Zero-Energy Automated Windows Report

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1. Executive summary

Most windows we install in our homes drain energy when compared to a wall. As a result, up to 20% of residential energy is lost through windows while we try to keep our homes at a comfortable temperature. Windows are no doubt necessary for a healthy, comfortable living environment, but can we eliminate the energy loss? Further, can our windows do more to make our homes safer, and help us sleep better?

A group of scientists in the Lawrence Berkeley National Laboratory (LBNL) has found a solution. In a project funded by the Department of Energy, Christian Kohler and his colleagues created a zero-energy window that would consume/lose the same amount of energy as a wall. The window has four key components – multiple layers of glasses, motorized shades, environment and motion sensors, as well as a microchip. The window delivers superior energy performance by significantly enhancing thermal insulation and intelligently optimizing heat absorption from sunlight based on weather conditions and occupant behaviors. Across different climates in the US, the window can save $150 - $270 per home, or 10%-20% of home energy use.

The window can also play a larger role in home security and sleep moderation. For example, a homeowner can remotely close the shades using their smart phone while they are on vacation. The shades could be connected to your alarm clock to wake your body up using natural sunlight, improving your sleep quality.

Guided by LBNL's wish to adopt an open-source approach, we have developed a two-step strategy to introduce the window design to the $6 billion residential window market. First, we have identified a market segment of high-income, tech-savvy early adopters who already try to create similar functionalities by integrating separate components of premium windows, standalone motorized shades and a smart home system. Our window is price competitive after considering installation cost savings. To reach this market segment, we recommend sharing price analysis and technical knowhow with major window manufacturers such as Pella and Anderson. In addition, the laboratory should collaborate with smart home service providers to include the window in their product offerings.

For the mainstream market, the $50 to $80 per square foot price gap between our zero-energy window and the most common window products poses a significant adoption barrier, since mainstream consumers are generally more price sensitive. From our survey with 200 US households, we find that 30%-50% of consumers would likely upgrade to zero-energy windows if the price gap is narrowed to $25 per square foot. We encourage the laboratory to work with window manufacturers and distribution channels to achieve such

price level. The laboratory should also explore other avenues to narrow the price gap. For example, the laboratory could lobby for federal tax credits, which are offered for a wide range of energy efficient devices. Utilities could also be a valuable partner to incorporate the window into their demand response and energy efficiency rebate programs.

2. Introduction to the technology

2.1. Background

The US Department of Energy (DOE) has set challenging energy targets for residential windows that would provide exceptional insulating performance while effectively managing solar gain in both heating and cooling seasons. Such windows are technically feasible but are not currently available in US markets. In 2012, the Department of Energy (DOE) awarded $1.5 million in funding to the Lawrence Berkeley National Laboratory (LBNL), in partnership with Pella Windows, to create a technology platform for a new generation of high performance windows and develop and field test the first window that will meet DOE energy and cost targets.

The goal of LBNL is to develop a cost-effective (an incremental cost of < $12/sq. ft.) and highly insulating residential window that maximizes solar gain in the winter and minimizes solar gain in the summer. Fully automated operation to optimize energy savings is enabled by an intelligent, networkable, sensor/microprocessor package that is integrated into the window frame.

LBNL has previously analyzed and verified that windows in cold climates can be net energy producers in homes.[1] The challenge is to provide very low heat-loss rates (low U-factor), and also reliably control the solar heat gain coefficient (SHGC). A high transmission of solar irradiance in the winter months enables passive heating of the house and a high rejection of solar irradiance in the summer reduces the passive heating of the house through the windows. Hence LBNL's proposed solution is to design a multi-glazed, highly insulating residential window with integrated, automated shades.

2.2. Product characteristics

To design a zero-energy window, LBNL has proposed a multi-glazed highly insulating window with a U-value under 0.14 a variable and SHGC between 0.18-0.46. The U-value is achieved by using 3-4 highly insulating layers of glass that are filled with gas. The variable SHGC is achieved by using automated shades that are integrated with the window. The automated shade is installed with a glass-backing layer in order to improve rejection of incident solar radiation. Also integrated into the window is a sensor and control package to track indoor/outdoor temperature, occupancy and enable wireless communications. The research group at LBNL has developed optimal control algorithms to automate the shades and maximize the energy savings that are possible from the windows. Figure 1 shows the performance of 3 different glazing options identified by LBNL that satisfy the DOE U-factor

[1] *Arasteh, Apte, Selkowitz, LaFrance. "Zero-Energy Windows", ACEEE, 2006*

and SHGC targets for zero-energy windows. Figure 3 shows an example of a zero-energy windows as developed by LBNL. This window has 4 layers of glass and an integrated shade with a backing layer.

Description	# glass layers	# coatings	# gas filled cavities	U (BTU/hr-ft2-F)	SHGC (-)
FOA Target	X	X	X	≤0.14	≤ 0.18 and ≥ 0.45
Baseline - Energy Star	2	1	1	≤0.30	ANY
State-of-the-Art	3	2	2	~0.20	~0.25
Opt. 1	3	3	1	~0.15	≤0.18 & ≥0.46
Opt. 2	4	3	2	~0.12	≤0.17 & ≥0.48
Opt. 3	4	4	2	~0.11	≤0.14 & ≥0.45

Figure 1: Preliminary window performance and configuration options in comparison to the funding opportunity announcement (FOA) of the DOE.[2] Options 1, 2, and 3 represent 3 possible glazing options to meet the FOA target.

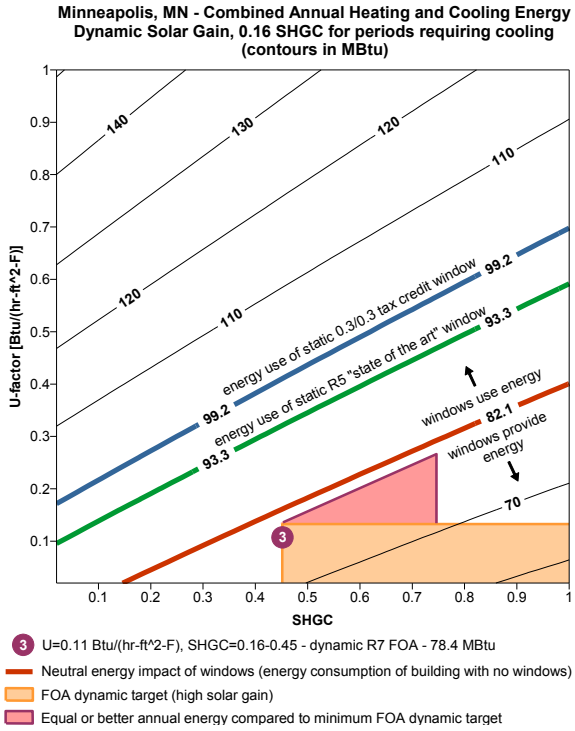


Figure 2: Simulated annual energy performance of dynamic prototype[2]

[2] *LBNL DOE Grant Proposal: Highly insulating Residential Windows Using Smart Automated Shading*

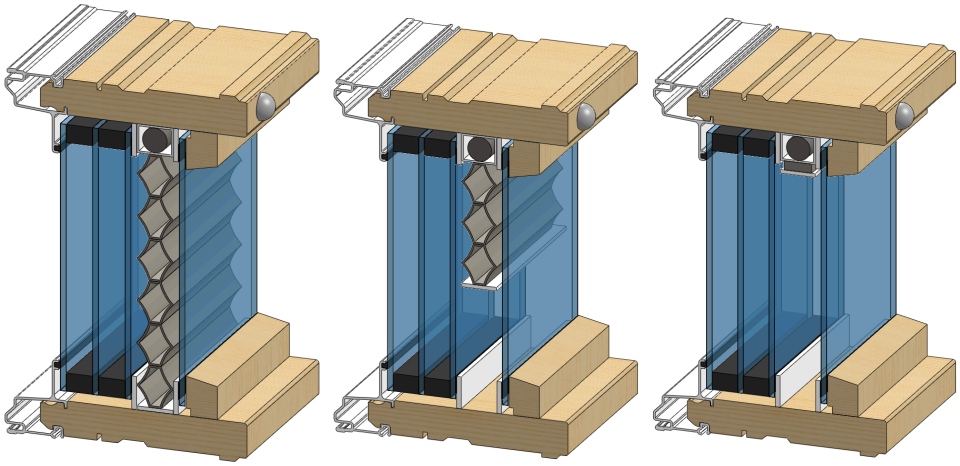


Figure 3: Zero-energy window as proposed by LBNL.

2.3. Energy performance of zero-energy automated windows

LBNL has done extensive research on the performance criteria for residential zero-energy windows.[3] A representative single-family house, which is 2,000 ft² with 300 ft² of windows distributed equally on all four orientations was simulated using a house energy-modeling tool: DOE-2. Typical efficient window products are evaluated in five US climates (Minneapolis MN, Salt Lake City UT, Washington DC, Riverside CA and Charleston SC) and compared against the requirements for Zero-Energy Homes. A database of the annual energy consumption (both heating and cooling energy use) of various types of windows with different U-factors and SHGCs is created based on the simulation results.
We compared the annual energy consumption of the different energy-efficient windows developed by LBNL with common residential window types.

The types of windows compared were:

a) ENERGY STAR windows with automated interior shading,
b) triple-pane windows with automated integrated shading,
c) four layer windows,
d) four layer windows with automated integrated shading (LBNLs zero-energy automated windows), and
e) double-clear windows with automated shading.

They were compared with

a) single-pane-clear windows,

[3] *Dariush Arasteh, Howdy Goudey, Joe Huang, Christian Kohler, Robin Mitchell." Performance Criteria for Residential Zero-Energy Windows".*

b) double-pane-clear windows, and
c) ENERGY STAR windows.

Figure 4 presents how much energy the automated windows can save in different climates across the US compared to common residential window types. Based on the results of this table, even compared to the current, state-of-art ENERGY STAR windows, the automated zero-energy windows still have absolute advantages in terms of annual energy savings. One of the key takeaways from the energy performance analysis is that in milder, mixed climates (i.e. climates where both heating and cooling needs are not extreme), dynamic SGHC is more important than a low U-factor. Hence, we recommend tailoring the number of layers of glass to specific climate types, which will reduce the price of the windows.
Figure 5 presents the energy savings possible by LBNL's zero-energy windows in comparison to double clear windows across the US; double clear windows are the most common windows purchased by the residential market. The automated zero-energy windows can help households reduce their annual utility bill from as much as $150 in mild climates (California), to as much as $277 in cold climates (Minnesota).
Currently, residential space heating/cooling energy use accounts for 10% of total US energy consumption (Figure 6), This represents a large opportunity for LBNLs zero-energy automated window. Hypothetically, if all the households in the US were to replace their regular windows with the automated zero-energy windows, the total amount of energy savings would equal to 14% of the electricity generation from the coal power plants in US.

Energy Saving Comparison

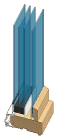
						Single clear		Double clear		EnergyStar window	
											
					U factor	0.84		0.49		0.34	
					SHGC	0.64		0.56		0.3	
Window type	U factor	SHGC	Description	City	Climate Zone	kWh	$	kWh	$	kWh	$
	0.34	>=0.46 & <=0.18	Double, low-gain, low-E, Ar + automated shading	Minneapolis, MN	Very cold	2733	$305	1086	$115	694	$76
				Salt lake city, UT	Cool & dry	2154	$178	998	$79	698	$59
				Washington, DC	Mixed & marine	2087	$256	1032	$108	686	$85
				Riverside, CA	Warm&marine	1368	$162	885	$101	703	$69
				Charleston, SC	Warm & dry	1703	$165	1167	$98	666	$70
	0.15	>=0.46 & <=0.18	Triple + automated shading	Minneapolis, MN	Very cold	3874	$445	2227	$254	1835	$216
				Salt lake city, UT	Cool & dry	2966	$253	1811	$153	1510	$133
				Washington, DC	Mixed & marine	2815	$368	1760	$220	1414	$198
				Riverside, CA	Warm&marine	1653	$203	1171	$142	989	$110
				Charleston, SC	Warm & dry	2015	$214	1478	$147	977	$119
	0.14	0.48	Four layers	Minneapolis, MN	Very cold	3618	$434	1971	$244	1580	$205
				Salt lake city, UT	Cool & dry	2579	$230	1423	$131	1123	$111
				Washington, DC	Mixed & marine	2330	$341	1275	$193	929	$170
				Riverside, CA	Warm&marine	1036	$138	553	$76	371	$45
				Charleston, SC	Warm & dry	1127	$149	590	$82	89	$54
	0.14	>=0.48 & <=0.17	Four layers+ automated shading	Minneapolis, MN	Very cold	4066	$468	2419	$277	2027	$239
				Salt lake city, UT	Cool & dry	3112	$266	1956	$166	1656	$147
				Washington, DC	Mixed & marine	2947	$388	1892	$240	1546	$218
				Riverside, CA	Warm&marine	1712	$212	1229	$150	1047	$118
				Charleston, SC	Warm & dry	2046	$219	1509	$152	1008	$124
	0.49	>=0.46 & <=0.18	Double clear + automated shading	Minneapolis, MN	Very cold	1795	$191	148	$0	-243	-$38
				Salt lake city, UT	Cool & dry	1493	$118	338	$18	37	-$2
				Washington, DC	Mixed & marine	1491	$165	436	$17	90	-$6
				Riverside, CA	Warm&marine	1127	$128	645	$67	463	$35
				Charleston, SC	Warm & dry	1462	$127	925	$61	425	$32

Figure 4 Energy Saving comparison of different configuration of LBNL developed energy-efficient window types to common residential window types. Window type 4 with four-layers and automated shading is a zero-energy window.

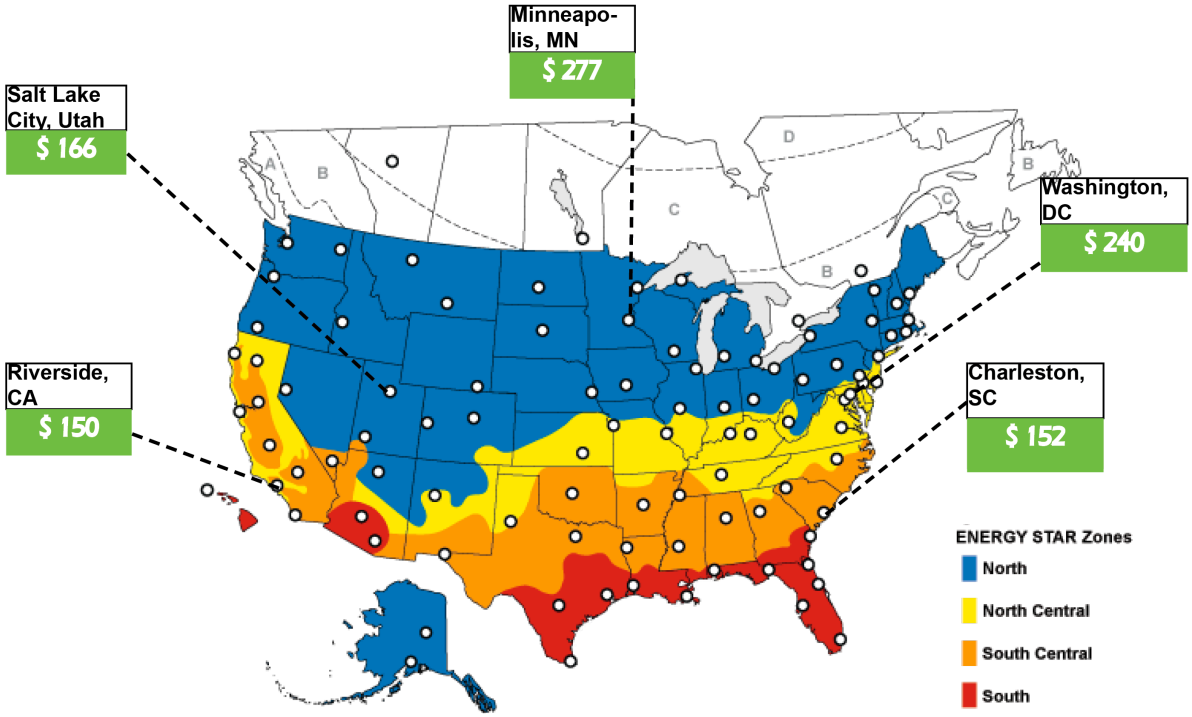


Figure 5: Annual energy savings per household possible by replacing double-clear windows with zero-energy automated windows in different climate zones.

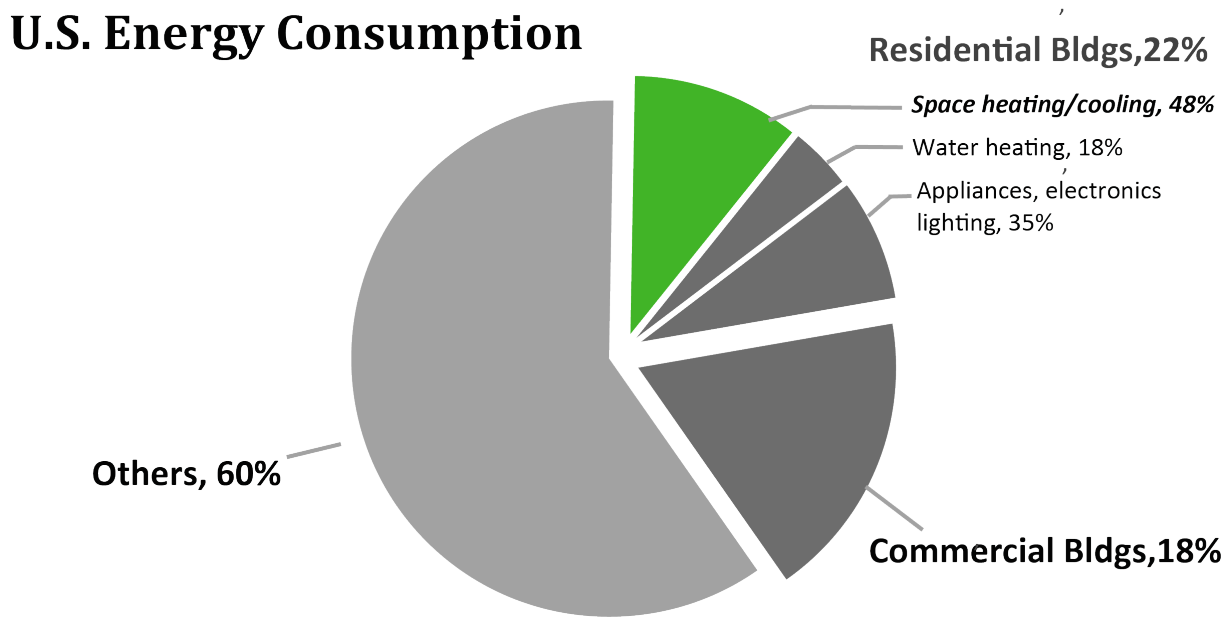


Figure 6: US Energy Consumption

2.4. Product Features

From our interviews with customers and retailers we decided that the best way to position the zero-energy automated window in the market is by explaining what its key features and benefits are.

What are the key features of the zero-energy automated window?

Integrated solution: The zero-energy automated window has four key components integrated in a single product: (i) an integrated shade motorized shade with automated controls, (ii) a group of sensors that measure indoor/outdoor temperature, incident solar radiation, and occupancy, (iii) wireless connectivity, and (iv) an automated control scheme that implements an energy-saving algorithm.

Customizable size: The zero-energy automated window can be customized to fit into any type of fenestration.

Compatibility with home automation systems: The window will integrate wireless functionality into the sensor package. Therefore our windows will be able to connect to smart home systems.

Smooth & Quiet Operation: Thanks to its high performance motor, the shade operation will be quick, smooth and quiet.

What are our product benefits?

Energy Savings: The zero-energy window provides substantial energy savings over existing windows due to its high U-factor and dynamic SHGC

Security/Privacy: The window will have the option to be connected to a home alarm system and mobile devices. This will enable the remote control of blinds and potentially reduce theft.

Comfort: As already explained, the window can be connected to an existing smart home system. The home system will have information of contextual awareness: knowing what the user is doing and how is he feeling. Our windows can adapt to user needs. For example: if the user is watching a movie the shades can operate for optimum visibility. If the user is tired, the shades can automatically close to enhance the sleep environment.

Health: Research has shown that exposure to natural light has many health benefits. Our window can be automated to maximize the exposure to natural light when the user is at home. The windows can be programmed to open their shades to gradually let in daylight in the morning and enhance the wake up experience.

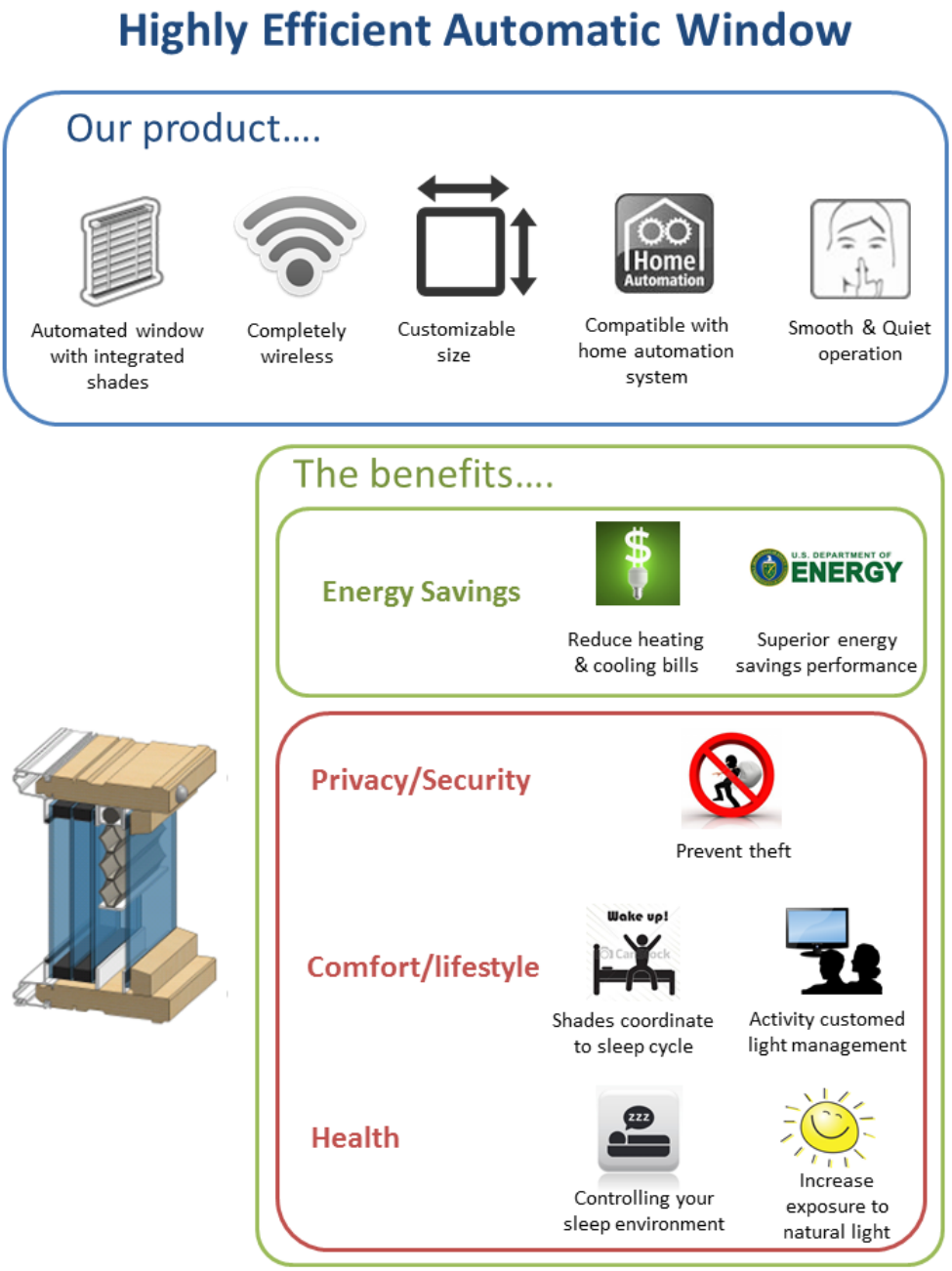


Figure 7: Product brochure that was developed to explain the zero-energy automated window during our interviews.

3. Markets & Opportunities

3.1. Approach Overview

We were tasked by LBNL to find out the mainstream market's willingness to pay for this zero-energy automated window. However, our team also wanted to assess other potential markets for initial market entry and other long-term market opportunities as well. Our market research consisted of four phases, after which we eliminated some of the unattractive markets:

1. First, we diverged and brainstormed thirteen value propositions.

2. Second, we narrowed down to nine value propositions based on their value and potential market sizes.

3. Finally, in addition to the residential market that our scientists are primarily interested in, we have identified three other markets that our scientists should consider in future.

After we completed our market assessment, we came up with recommendations on how LBNL should approach the mainstream residential market with some suggestions for the long-term market entry.

3.2. Value Propositions (Diverging)

At the diverging phase, we brainstormed a number of potential value propositions for our window. We captured an extremely broad scope of market opportunities, which consequently included some non-obvious potential applications. To do this we thought of buildings that either had a large number of windows or those that consumed a large amount of energy. To narrow down from this initial brainstorming phase we carried out interviews and conducted research for the various markets to verify their value and estimate the market size. This is shown in **Table 1**

Potential Value Propositions	Value	Addressable Market Size	Retained / Eliminated
Energy Efficiency for Buildings	✔	Large	Retained
Automatic Daylight Control for Buildings	✔	Large	Retained
Demand Response	✔	Medium	Retained
Sleep Cycle Regulation for Areas with Extreme Day Cycles	✔	Medium	Retained
Remote Shading Control for Mobility Challenged Patients	✔	Medium	Retained
Temperature and Daylight Control for Trains	✔	Medium	Retained
Temperature and Daylight Control for Planes	✔	Medium	Retained
Energy Efficiency for Air-conditioned Stadium	✔	Small	Eliminated
Sleep Cycle Regulation for Astronauts	✔	Small	Eliminated
Extra Space for Building Exterior Ad Space	✖	Large	Eliminated
Asset Preservation for Museums, Art Galleries, Libraries	✖	Medium	Eliminated
Collision Prevention for Bird Zoos	✖	Medium	Eliminated
Harvest Enhancement at Fish Farms	✖	Medium	Eliminated

Table 1: Potential Value Propositions

3.3. Market Segments

Next, we identified a number of market segments that could benefit from the value propositions we identified. Different market segments benefit from a wide variety of the aspects of zero-energy automated windows and value each of these aspects differently. For example, homes can derive a benefit from all the various value propositions of zero-energy automated windows. On the other hand, segments like utilities and greenhouses benefit from fewer aspects, but have strong incentives to adopt because of regulatory requirements and high-energy consumption respectively. This breakdown is shown in Table 2

	Homes	Commercial	Hospitals	Hotels	Greenhouse	Utilities	Planes	Trains
Energy Efficiency	✔	✔	✔	✔	✔	✔	✔	✔
Daylight Control	✔	✔	✔	✔	✔	✖	✔	✔
Temp. Control	✔	✔	✔	✔	✔	✖	✔	✔
Security & Privacy	✔	✔	✔	✔	✖	✖	✖	✖
Remote Control	✔	✔	✔	✔	✖	✖	✔	✔
Sleep Regulation	✔	✖	✔	✔	✖	✖	✔	✔
Demand Response	✔	✔	✔	✔	✔	✔	✖	✖

Table 2: Market Segments and Value Propositions

3.4. Most Promising Markets (Converging)

To guide our deep dive efforts, we weighed each customer segment against the following four criteria:

a. Willingness to Pay - how big is the pain point and how high is the switching cost?
b. Market Size – annual spending on windows
c. Time to Market – length of a sales cycle, concentration of buyers, regulatory barriers
d. Competition from Other Technologies – prevalence of existing technologies that can achieve similar levels of energy saving, comfort, or convenience

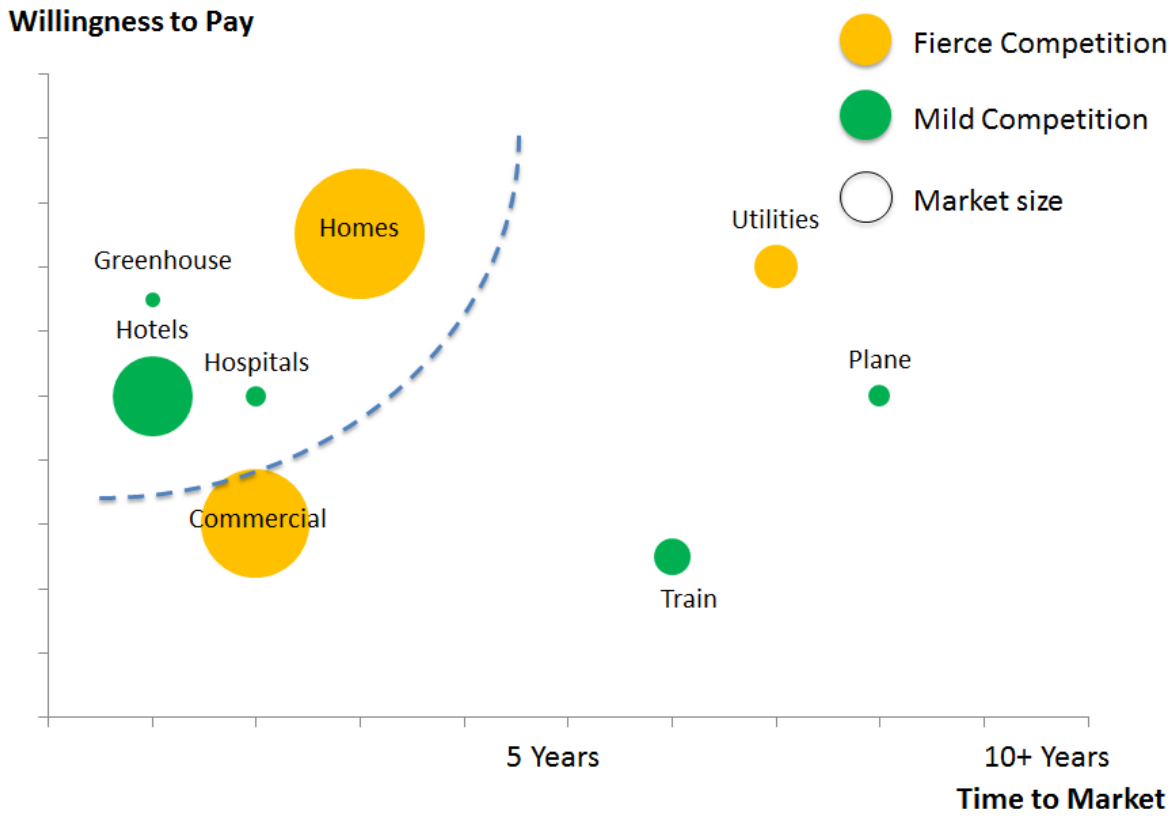


Figure 8: Eliminating Market Segments Based on Four Criteria

After interviewing a number of industry experts, we managed to obtain an understanding how each market segment measures against our criteria. Ideally, we want to target customer segments that have high willingness to pay, short time to market, large market size, and little competition from other technologies. From Figure 8, we identified four key markets that we felt were the most favorable: homes, hotels, hospitals, and greenhouses.

Although LBNL's main objective is to focus on the residential market, we recommend that they also consider other customer segments such as greenhouses, hotels and hospitals; these are customer segments that saw great value in both the energy and automation values associated with the zero-energy automated windows.

4. US Residential Market

In this section we present the relevant current trends in the residential windows market and also explore the competitive landscape.

4.1. US Residential Windows Market Trends and Recommendations

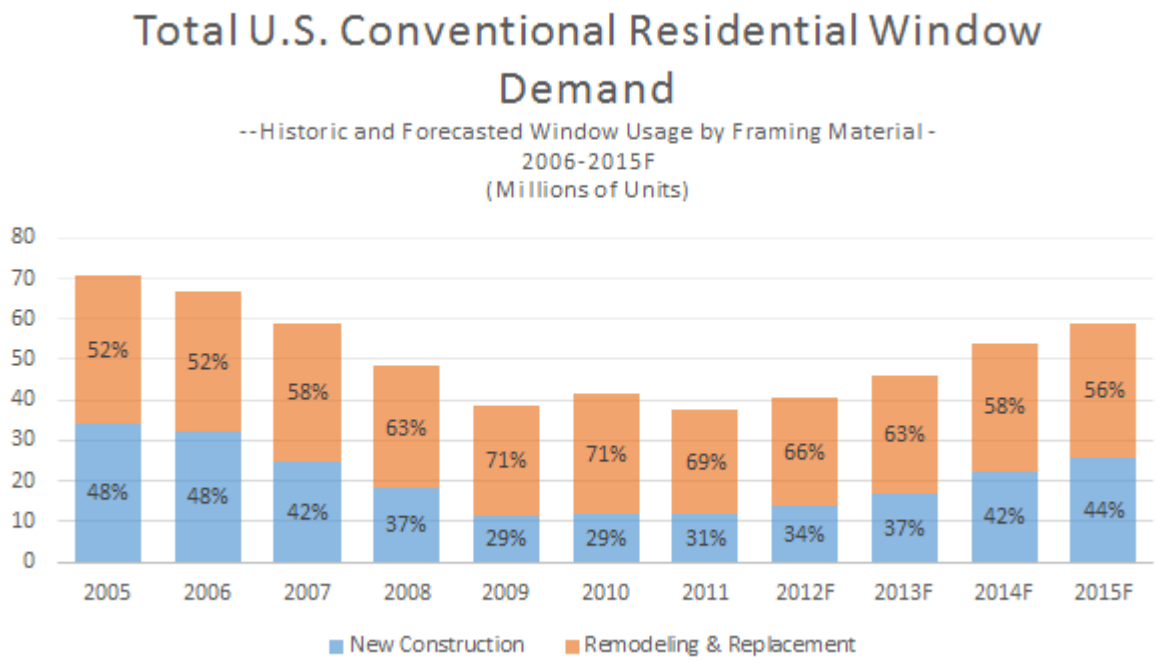


Figure 9: Total US conventional residential window demand[4]

We can see that from both historical and projected data of residential window sales that the remodeling & replacement market for residential windows is larger than the new construction market (Figure 9). This phenomenon was more extreme during the economic crisis, where new construction was depressed and the retrofit market accounted for nearly 71% of residential window sales. However, even post-recovery projections show that the remodeling & replacement market will account for a larger share of residential windows sold. We feel that based on the market data there is a definite incentive to prioritize the replacement & remodeling market over the new construction market. In addition our interviews with new home developers indicated that they are more risk-averse than individual homeowners. New home developers indicated that the incentives in installing zero-energy automated windows were not in line with their traditional business models.

[4] *Study of the US Market For Windows, Doors and Skylights, Ducker Research Company, Inc.*

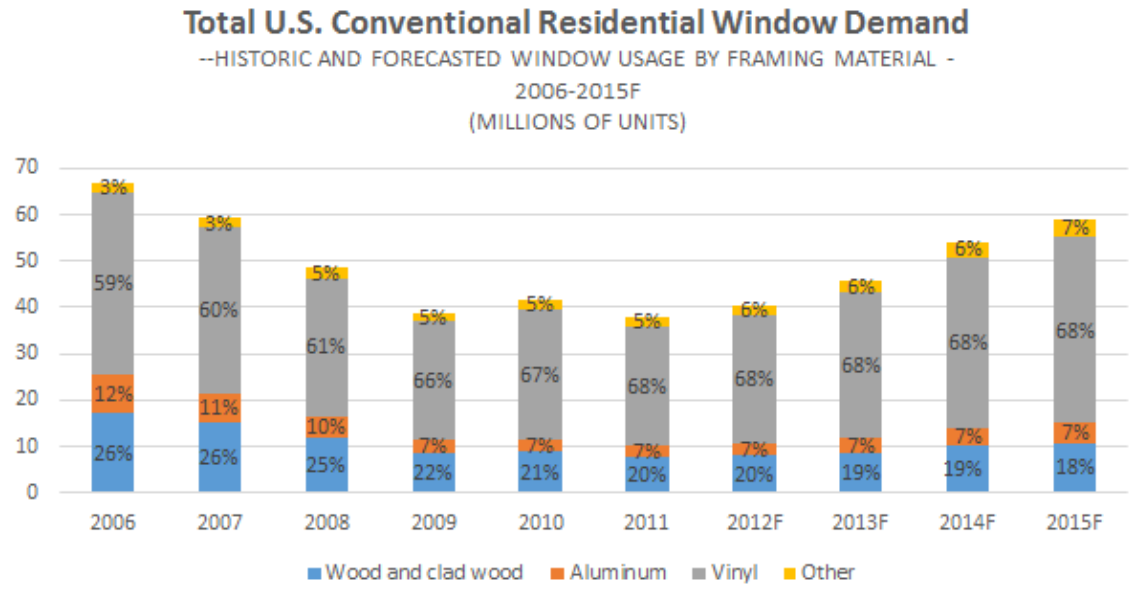


Figure 10: Total US conventional residential window demand, segmented by framing material [4]

The windows market is traditionally differentiated based on the framing material. Wood and aluminum are premium framing-materials and have a higher per unit cost than vinyl. This is reflected in the market data, vinyl is the most common framing material. From Figure 10 we can see that vinyl window units have continued to increase their market share of the residential market. Since wood is a premium framing-material, we recommend that zero-energy automated windows that are aimed at the early-adopter market should use wood frames. Subsequently, windows that are aimed for greater market penetration should be offered with vinyl frames.

4.2. Competitive Landscape

The zero-energy automated window's most unique feature is the integrated nature of the product. Our product integrates a number of components and features that no other product in the market offers. Nevertheless, a subsection of the features of the zero-energy automated window can be obtained by separately buying and integrating components from a few different manufacturers.
Currently, residential customers have the following alternative options to obtain some of the same features as the zero-energy automated window:

(i) traditional window with a separate manual shade,
(ii) traditional window with a separate motorized shade,
(iii) traditional window with and integrated shade, and
(iv) smart glass.

It is important to note that none of these alternatives provide all the benefits that the zero-energy automated window offers.

Potential Value Propositions	Integrated solution	Super highly energy efficient	Connectivity to smart home	Security features	Health features
Zero Energy Automated Window	✔	✔	✔	✔	✔
(i) Windows + manual shades	✖	✖	✖	≈	≈
(ii) Windows + automatic shades	✖	✖	≈	≈	≈
(iii) Windows with integrated manual shades	✔	✖	✖	≈	≈
(iv) Smart Glass	✔	✖	✔	✔	✖

Table 3: Comparison of the features offered by market alternatives to zero-energy automated windows.

Table 3 provides a comparison of the features that the zero-energy automated window offers in comparison to current market alternatives.

Company	Annual Sales	Market Targeted	Product Lines
Andersen	> $1 Billion	Premium + Mainstream	Wood windows and patio doors. Composite replacement windows. Vinyl windows and doors.
Formosa Plastics Group	> $1 Billion	Mainstream	Fiberglass entry doors and composite frames. Fiberglass patio door systems. Vinyl window and door systems
Jeld-Wen Inc.*	> $1 Billion	Premium + Mainstream	Wood, vinyl, and aluminum windows and patio doors. Wood, steel, and composite entry doors. Interior doors. Millwork products.
Masonite International Corp.	> $1 Billion	Premium + Mainstream	Steel, wood, fiberglass and composite entry and patio doors. Interior doors, French doors, and bi-fold doors.
Pella Corp.*	> $1 Billion	Premium + Mainstream	Wood, vinyl, fiberglass window, patio door and entry door products, as well as steel entry doors. Architectural windows, curtain wall, storefronts and entrances.

Table 4: Top windows manufactures in the US.

Table 4 highlights key characteristics of the major US residential window manufacturers. Although we highlight traditional windows as an alternative to zero-energy automated windows, it is important to note that the goal of LBNL is to partner with current window manufacturers and license their technology to introduce zero-energy automated windows to the residential market. Therefore, we consider these companies as possible clients/partners rather than competitors.

Currently, some of the major windows manufacturers offer triple-pane windows, however, none of them are offer a four-pane window. This is because the energy saving from the additional insulation offered by a four-pane window is not high enough in all but the coldest of US climates to justify the additional expense.

4.2.1. Traditional Windows with Manual Shading

A traditional window with manual shading is the simplest and most commonly installed window/shade configuration for residential customers. The shading is typically installed separately after the windows. The market for traditional manual shades is very fragmented with a lot of players. From our interviews the average price of these shades is in the range of $50-100/shade for a 3x2 feet window with an installation cost of $25 per unit.

Figure 11: Manual shade example

4.2.2. Traditional window with non-integrated automatic motorized shades

Motorized shades are available from all specialty shades dealers. These shades usually are battery-powered needing a replacement every 2 years, however, there are also solutions that integrate PV panels.
The key players in this market are Serena, Somfy, Bali, Pella Windows and Lutron. Table 5 provides a breakdown of the price of the different brands of motorized shades.

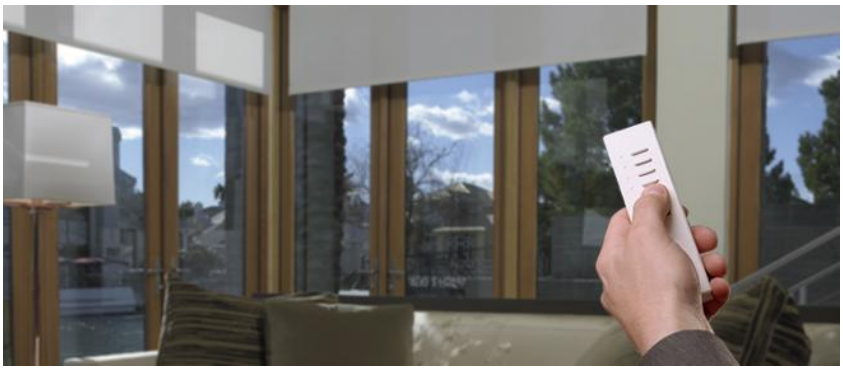


Figure 12: Motorized shade example

Brand	Type	Price ($)
Serena	Batteries with IR remote control	280
	Batteries with RF remote control	305
Bali	Batteries Solar powered:	428
	Plug-in (transformer):	366
Allen & Roth by Vista Products	Batteries	400
	Plug-in (transformer):	470

Table 5: Cost of the different motorized shade alternatives[5]

4.2.3. Integrated manual shade

There are a few window manufacturers (Pella and ODL) offering a product with integrated shading between the layers of a double-pane window. However, the energy performance of these products is quite poor due to the fact that the back layer is not permanently sealed to allow for servicing the integrated shades.

Figure 13: Manual automatic shade example

[5] *Source: Interview in Lowes (More detail in Interview Appendix)*

4.2.4. Smart Glass/Electro-chromic coatings

With smart glass it is technically difficult to reach the zero-energy window performance goals. Additionally current electro-chromic coatings are not able to block light as well as physical shades so they cannot offer the same health and security benefits as zero-energy automated windows. Additionally, these solutions tend to be more costly.

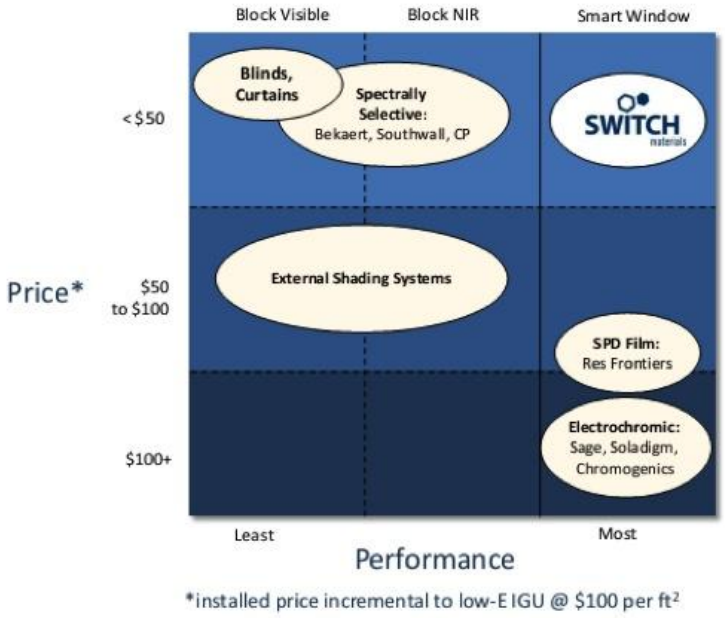


Figure 14: Price/Performance of the Electro-chromic and other solutions

4.3. Product Costs

In this section we will analyze the current price of manufacturing zero-energy windows and how this cost compares to alternatives in both the high-end and mainstream market. The prices are based on estimates of component costs calculated by LBNL.

4.3.1. Premium cost associated with making a traditional double-pane window into a zero-energy automated window[6]

The additional components that have to be included to a regular double-pane window in order to turn it into a zero-energy window are shown below:

- Additional Window Costs:
  - Glass Layer: 1-2 additional layers of glass need to be added to improve the insulating performance of a standard double-pane window. Table 6 shows the cost of the different alternatives

Type	$/sf	$/m2
1+1 (single pane + single panel)	$1.00	$10.07
2+1 (double pane + single panel)	$1.85	$18.63
3+1 (triple pane + single panel)	$2.28	$22.96
2+2 (double pane + double pane panel)	$2.70	$27.19

Table 6: Cost of the additional layers of glass

  - Glass coating: The coating of the glass makes a big difference in the SHGC of the windows. Table 7 shows the cost of the different low-e coatings.

Type	Description	$/sf	$/m2
Clear	Clear	$0.38	$3.82
272	Sputtered on clear, coating on #2 or #3 (including suspended film)	$0.68	$6.85
366	Sputtered on clear, coating on #2 or #3 (including suspended film)	$0.68	$6.85
i89	Pyrolitic or Sputtered on clear	$0.98	$9.87

[6] *Source: LBNL*

180	Sputtered on clear, coating on #2 or #3 (including suspended film)	$0.68	$6.85
i89/180	Pyrolitic or Sputtered on clear	$1.38	$13.90
Starfire	Low-iron	$0.68	$6.85

Table 7: Cost of the coating

- Motorized shade:
  - Shade plus labor: Table 8 shows the cost of 2 possible shading materials.

Type	$/sf	$/m2
Linen white	$4.00	$40.29
Room darkening cotton white	$4.50	$45.32

Table 8 : Cost of the shade

  - Motor: The cost of the motor that will operate the shades is estimated as $50/unit.

- Controls: Table 9 shows the cost of the controls for both stand-alone and networked operation of the automated windows.

Type	$/window
Stand-alone	$20.00
Networked	$10.00

Table 9: Cost of the different controls

- Sensor: Table 10 includes the prices of the different sensors integrated into the window.

Type	$/window
Motion	$3.00
Indoor temperature	$1.00
outdoor temperature	$1.00
solar	$2.00
ALL	$7.00

Table 10: Cost of the sensors

- Labor: The cost of the labor to integrate all the additional components is estimated to be $10/unit.

- Power connection: Table 11 shows the price of the different components that need to be included to provide power to the various parts of the automated window. Power can be provided either by a user-changeable battery or a solar PV and battery combination.

Type	$/window
low voltage wire	$1.00
Battery	$10.00
Battery/Solar PV	$20.00

Table 11: Cost of the power

In order to visualize the costs, we have made a cost waterfall of the different components of the zero-energy price premium (see Figure 15). Since we are uncertain about the potential mark-ups of windows manufactures, wholesaler and retailers, we have included three mark-ups possibilities.

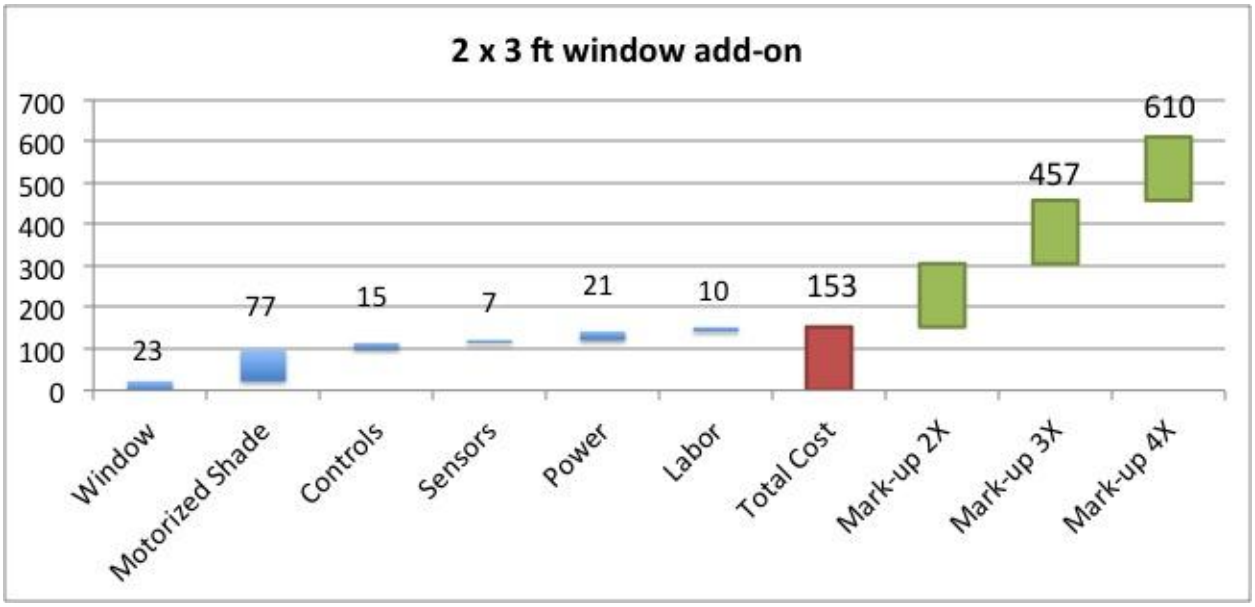


Figure 15: Cost waterfall of a 2x3 ft size Zero-energy Windows add-on.

4.3.2. Early adopter costs

Cost of the current market alternative: Figure 16 shows the price of a wood-frame window with an additional motorized shade. This number includes installation costs of both the window and the shade.

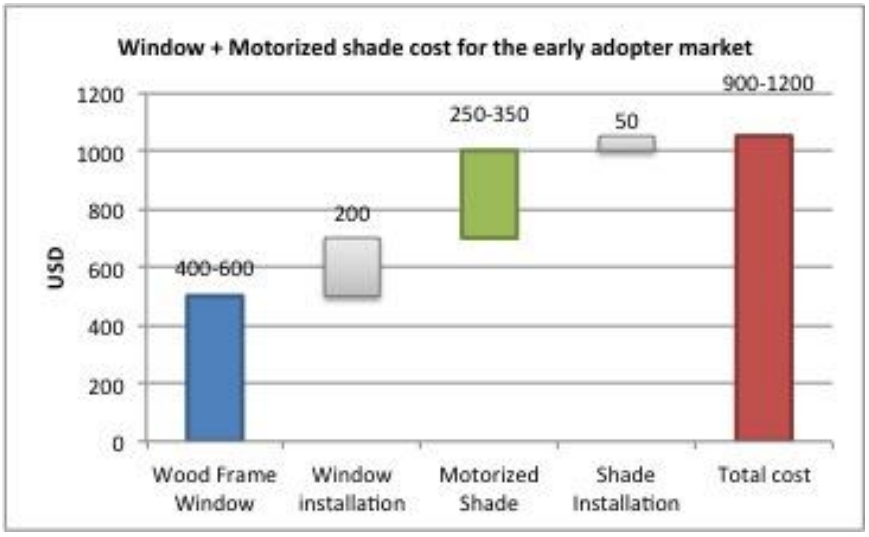


Figure 16: Cost of the Wood Window + Automatic shade for early adopter (2x3 ft size)

Cost of the Zero-Energy Window: Figure 17 shows the cost of the zero-energy window for the early adopter market. We assume a basic wood frame window and the zero-energy price premium with a mark-up in the mid-to-high range.

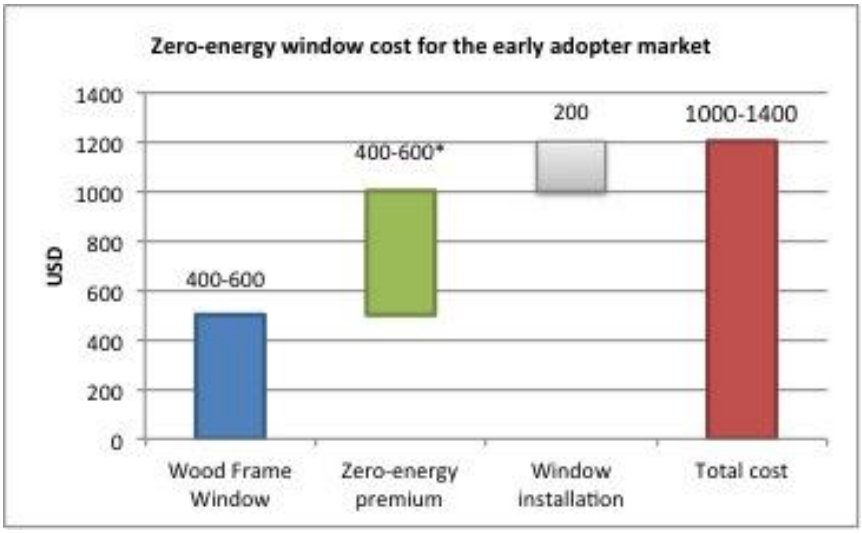


Figure 17: Cost of the Zero-Energy wood window for early adopter (2x3 ft size)

As we can see above, the price difference between the current alternative in the market and the zero-energy window product is quite low. We feel that the zero-energy automated window is priced competitively for early adopters and can be taken to the market at this stage.

4.3.3. Mainstream market

Cost of the current market alternative: Figure 18 shows the price of a vinyl double-pane window with an additional manual shade. This number includes the installation costs of both the window and the shade.

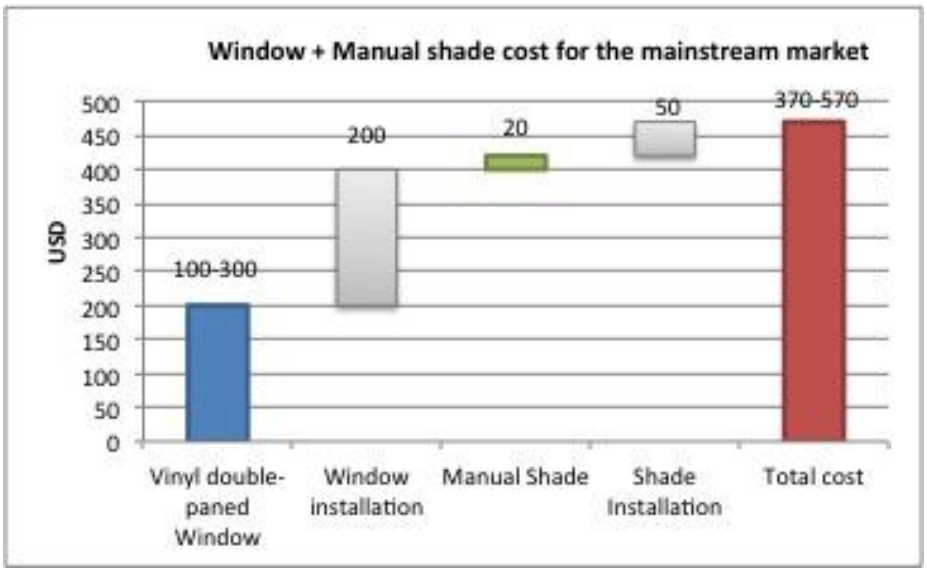


Figure 18: Cost of the Vinyl Window + manual shade for mainstream (2 x 3 ft size)

Cost of the Zero-Energy Window: Figure 19 shows the cost of the zero-energy window for the mainstream market. We assume a basic vinyl frame window and the zero-energy price premium assuming a mark-up in the low-to-mid range.

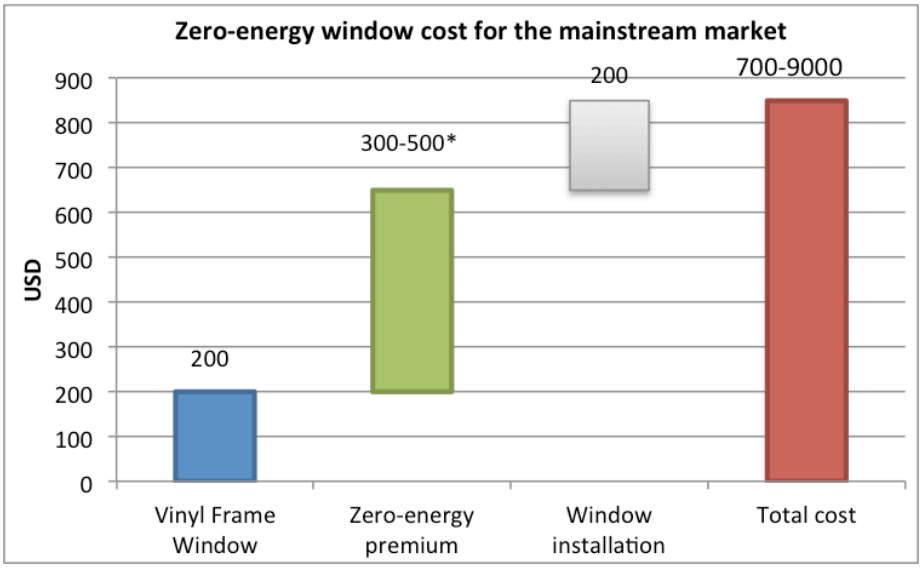


Figure 19: Cost of the Zero-energy window for the mainstream market (2 x 3 ft size)

As we see in these figures, there is a $300-500 cost difference between the current mainstream products in the market and the price of the zero-energy solution. We have carried out an extensive willingness-to-pay study to understand what the mainstream market is willing to pay for the additional non-energy features of the zero-energy automated window. The process and results are included in chapter 4.8.2 Willingness to pay.

4.4. Windows value chain

The window value chain is composed of four major categories (i) Raw Materials, (ii) Window assembly/manufactures, (iii) Windows Wholesaler/retail, and (iv) Windows installation.

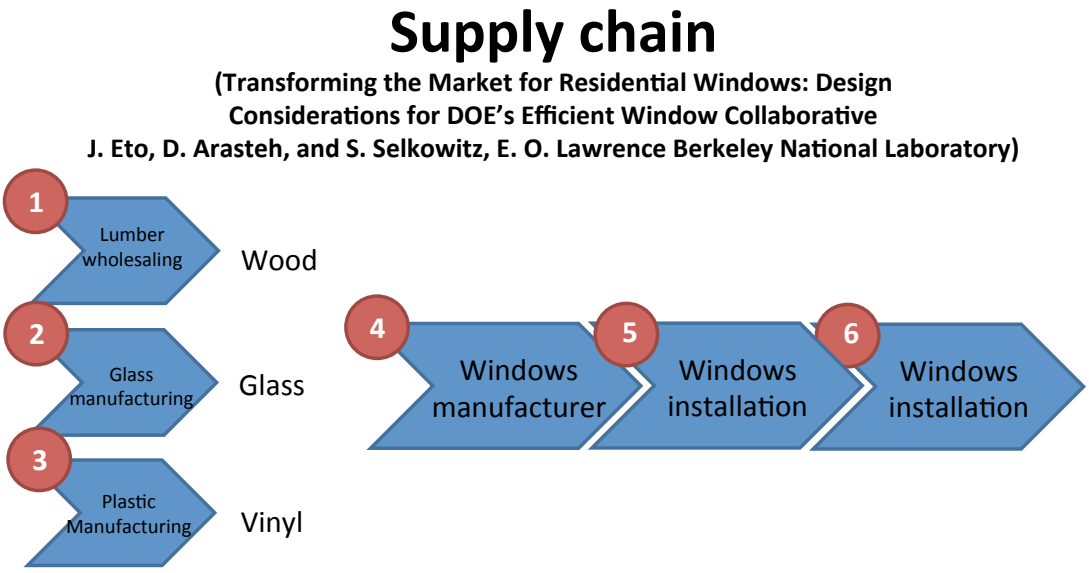


Figure 20: Supply chain of the windows market[7]

4.4.1. Raw materials

The most important raw materials for manufacturing windows are glass, lumber, aluminum and vinyl.
As we will see in the following sections, these materials are used in a lot of different products so they are mostly commodities with low margins.

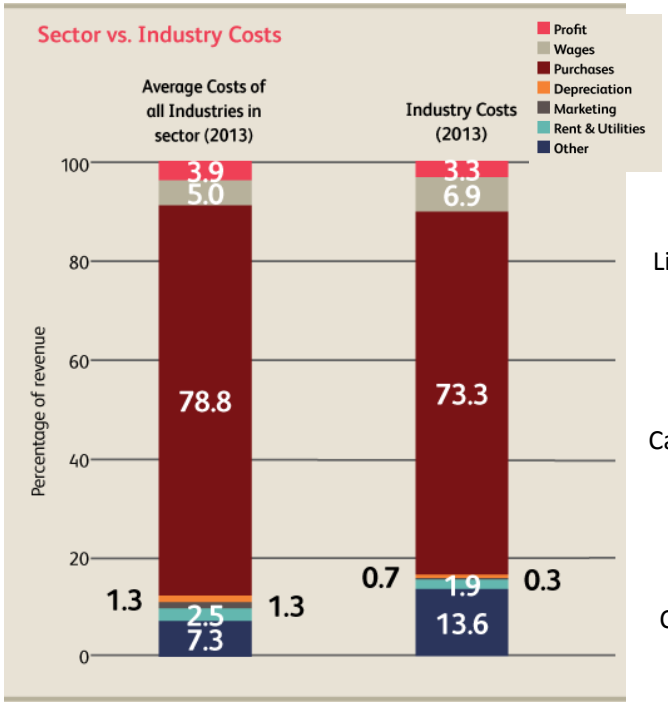
> **Wood:** Lumber wholesaling is a very competitive market with a large number of players. The technology and investments needed to be a player in this sector are low so the operational margins are in the range of 3%. 40% of the products from this industry go to the residential building market.

[7] *Source: http://clients1.ibisworld.com/*

1

Lumber Wholesaling in the US

This industry distributes a range of lumber, plywood, millwork and wood panel products to contractors, home improvement stores and hardware stores. The industry does not include wholesalers that distribute nonwood roofing and siding materials, nor does it include establishments that distribute timber and timber products such as railroad ties, logs, firewood and pulpwood.



Industry Structure

Life Cycle Stage	Mature	Regulation Level	Light
Revenue Volatility	Medium	Technology Change	Low
Capital Intensity	Low	Barriers to Entry	Low
Industry Assistance	None	Industry Globalization	Low
Concentration Level	Low	Competition Level	High

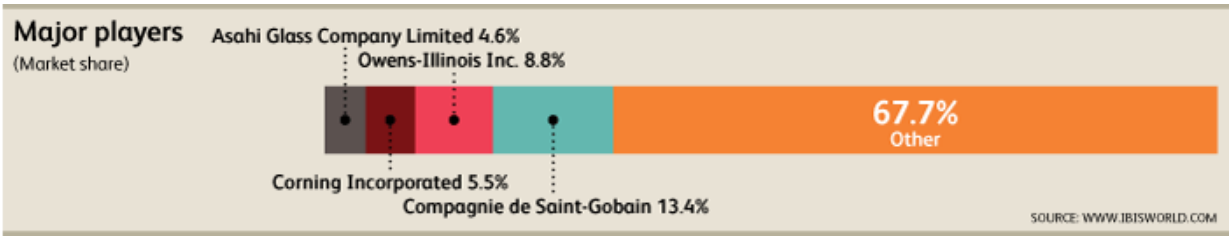
Figure 21: Lumber manufacturer industry

Glass: Four players control 65% of the market with an average operating margin of around 10%. 45% of the production from these glass manufacturers goes to the building and construction market. Due to the high investments needed to manufacture glass there are high barriers to entry.

2

Glass Manufacturer

Firms in this industry produce a wide range of glass products by melting silica sand or cullet and fabricating purchased glass. The industry comprises four segments: flat glass manufacturing (including laminated glass); pressed or blown glass and glassware; glass container manufacturing (including bottles and jars); and product manufacturing from purchased glass, which includes lighting, mirrors, architectural glass and electronic glassware



Industry Structure

Life Cycle Stage	Decline	Regulation Level	Heavy
Revenue Volatility	Low	Technology Change	High
Capital Intensity	Medium	Barriers to Entry	High
Industry Assistance	Medium	Industry Globalization	Medium
Concentration Level	Low	Competition Level	Medium

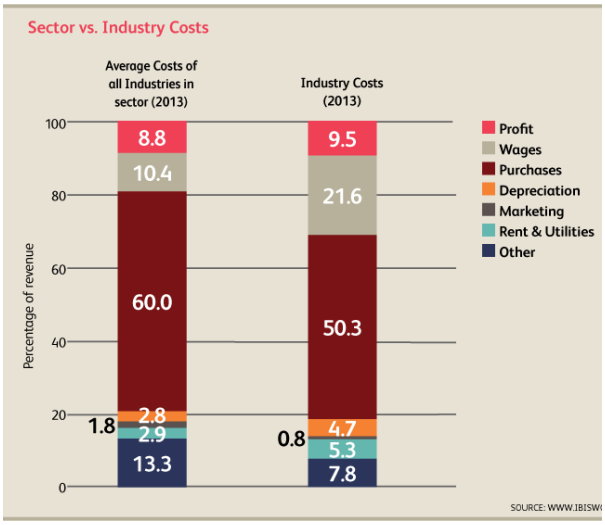


Figure 22: Glass manufacturer industry

Vinyl: Vinyl manufacturing is an industry with low concentration, Dow chemicals is the largest manufacturer and controls just 5% of the market. The average operating margin is around 5.5%. This industry has a medium barrier-to-entry due to the capital investments required.

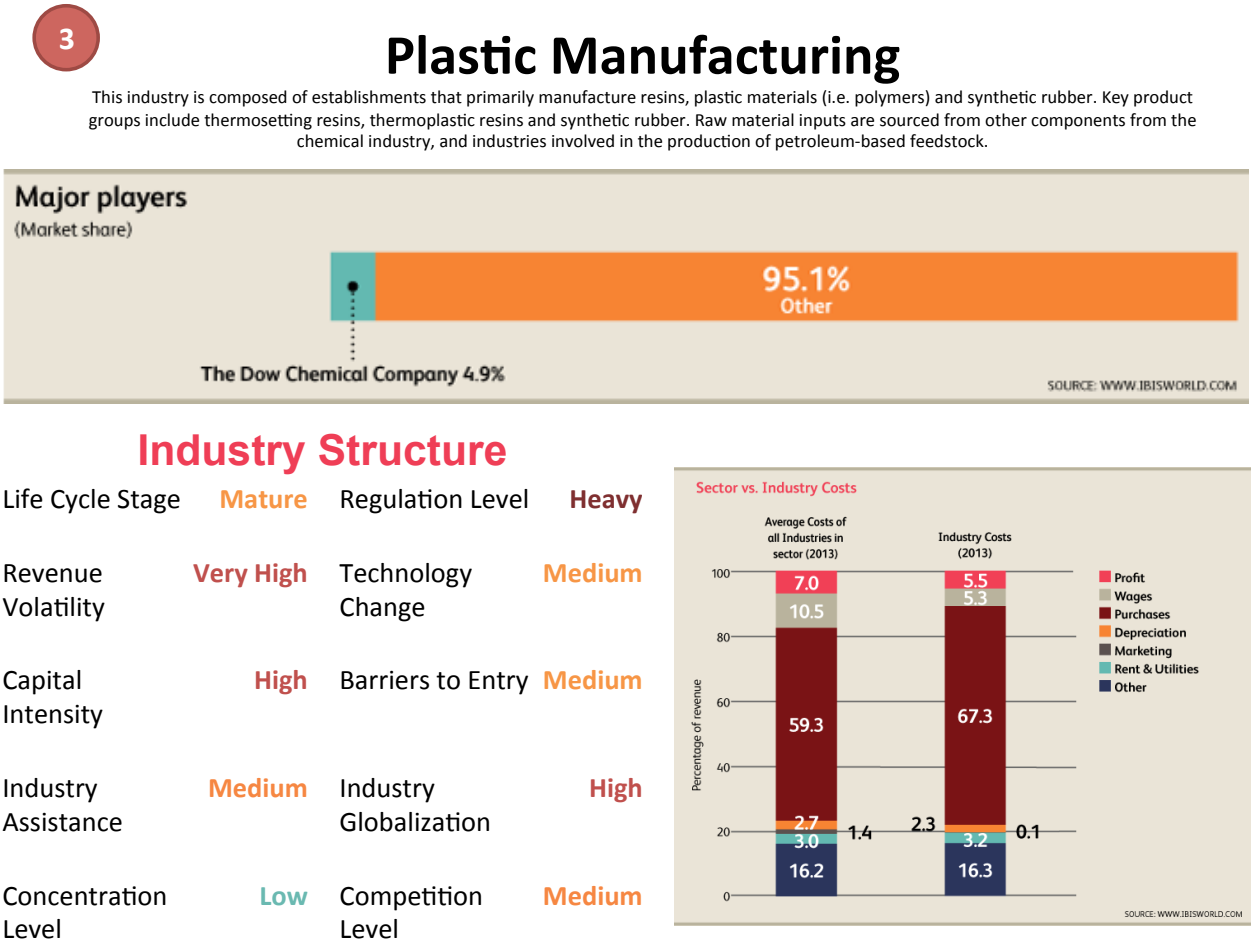


Figure 23: Plastic manufacturer industry

4.4.2. Assembly/Manufacturers

There are a lot of different windows manufacturers, the main players, as introduced in Table 4, are: Pella windows, Masonite, Andersen, Formosa and Jeld Well.

4.4.3. Wholesalers/Retailer

The main channels to the customer of the residential window market are the window retailers. This is the channel through which both homeowners and contractors choose and make decisions on which windows they are going to buy.

From our interviews (see interview template in 7.3 Appendix III) we learned that the wholesalers/retailers are organized into three major segments: home improvement stores,

local specialized stores and customized windows stores. The following graph shows the market share and price/window of the different segments:

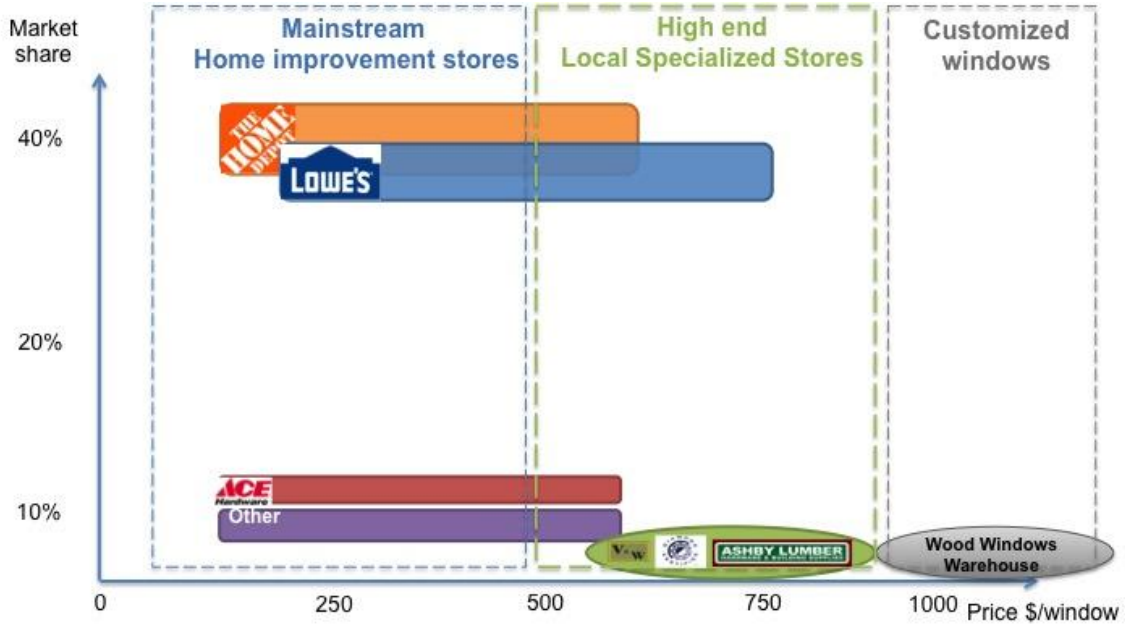


Figure 24: Windows wholesaler/retailers segmentation[8]

Home Improvement Stores: This group accounts for almost 90% of the market share. Home Depot and Lowes are the major national home improvement stores; each of them has around 35-40% of the market share. The home improvement stores offer an extensive portfolio of products coming from many different manufacturers. Most of their sales come in the form of mainstream windows; if customers are in the market for more specialized and premium windows and framing materials these stores will directly contact window manufacturers and sell them as well.

Local Specialty Stores: This group accounts for a smaller piece of the market. These stores are generally local stores, which offer a more personalized service to their clients. They will carry out a more customized analysis of the client's needs. These stores generally offer the more premium portfolio of products from fewer manufacturers, typically wood-frame windows. Some examples of the local specialty stores that we interviewed in Berkeley are Ashby Lumber and Diamond Certified windows retailers such as V&W Windows.

[8] *Source: Cost form interview and market share from Energy Efficient Home renovation market Report: SDI*

Customized Windows Stores: Customized windows stores manufacture their own products. In these stores, the client and the manufacturer custom design and build windows to match the need of their customers. This customization is the main reason of the high prices. We interviewed Wood Windows Warehouse, a local customized windows store in Berkeley.

4.4.4. - Installation

The installation of windows is a relatively easy job, in which no proprietary knowledge or technology is needed. In the residential market installers are generally contractors independently hired by homeowners or recommended by a window retailer. Most window installers charge an average of $200-300/window.

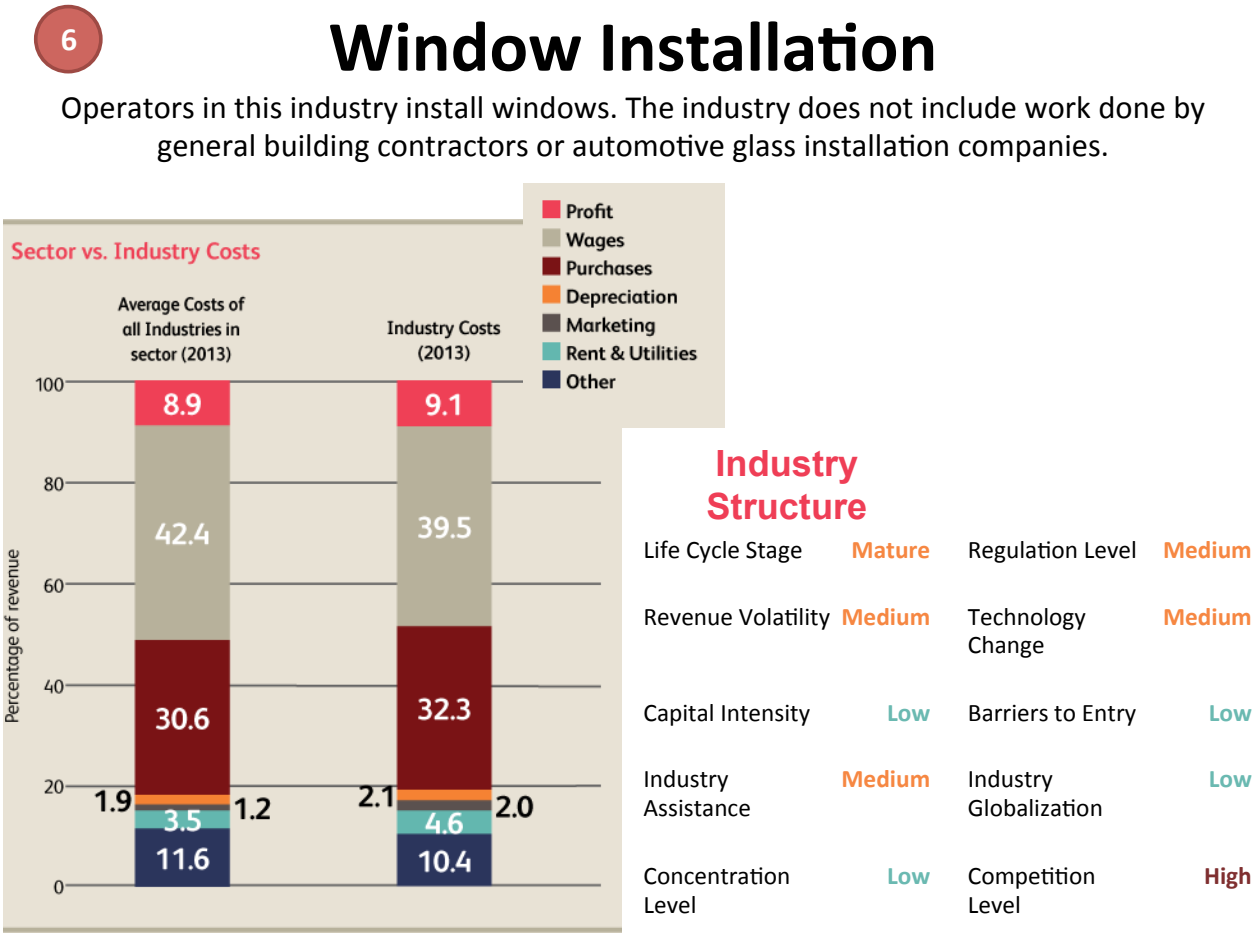


Figure 25: Windows Installation Industry

4.5. Regulatory environment

4.5.1. ENERGY STAR

ENERGY STAR qualified windows can reduce homeowners' energy bills up to 15% while helping protect the environment. However the windows must meet U-Factor and SHGC requirements based on DOE defined climate zones (see Figure 26).

	Climate Zone				
	2	3	4	5, Marine 4	6
U-factor	0.40	**0.35**	0.35	0.32	0.32
SHGC	0.25	**0.25**	0.40	NR	NR

Figure 26: ENERGY STAR windows requirements

4.5.2. Regulation and Policies

Currently, there are certain tax credits for windows. See Table below. One option is that we lobby for a greater tax credit since our windows provide a higher level of energy efficiency.

Tax Credit for Windows	
When?	2012,2013
How Much?	10% of the cost (not including installation/labor costs), up to $200 for windows and skylights;
Timing?	Tax credit in effect in 2012 and 2013. Must be installed in your "principal residence" between January 1, 2011 and December 31, 2013.
Qualifications	Must be ENERGY STAR qualified. You do not have to replace all the windows/doors/skylights in your home to qualify. And it doesn't need to be a replacement either - installing a new window where there wasn't one previously (like in an addition) qualifies.

Table 12: Tax credits

On top of tax credits, certain building codes that focus on energy efficiency, such as Title 24 in California,[9] can also provide incentives for contractors to implement our windows.

[9] http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF

4.6. Smart Home market

We were interested in finding out our opportunities to integrate within the smart home market. This section provides an overview of the market trends and the types of protocols used by the majority of home automation devices on the market.

4.6.1. Latest trends and market dynamics

The main applications for products on the home automation market at present are (i) lighting, (ii) home entertainment, (iii) security, and (iv) HVAC automation and home energy management. This market is projected to be $5.4 billion by 2016.[10] The majority of the home automation market is driven by retrofits in existing homes rather than installation in new homes. Although this trend was influenced by the US economic downturn, the retrofit market continues to account for 65% home automation revenue. Currently the market is segmented with many different providers for each of the applications.

As shown in Figure 28 below, the main channels for the full-home-automation market are integrated smart home installers. The full-home-automation market is a premium market and only represents about 5% of total home automation market. The main customers in this market are innovators and high-income early adopters who are drawn to the idea of having smart, automated appliances in their homes. We do not anticipate that our zero-energy automated windows will be a major product through this channel since smart home installers currently provide the functionality integrated into our automated windows using OEM sensors and actuators and use their more sophisticated home-controllers to integrate the systems together.

There are a few stand-alone smart appliances that have reached across the early adopters to the early mainstream market (ex. NEST smart thermostat). However, these devices are much lower priced and are also much easier to install than the zero-energy automated windows. We anticipate that there will be a few innovators who undertake building their own smart homes that might use our automated windows, but based on our research this is a very small segment of the home automation market.

Utilities provide a channel for HVAC management through demand-response using smart meters and programmable thermostats. This market is a large percentage of the total home automation market and expected to be nearly $1.2 billion by 2016. Using utility based demand-response programs we could provide a viable incentive to encourage adoption of our zero-energy automated windows.

[10] BCC research market research report, "The US Market for Home Automation and Security Technologies", By Andrew McWilliams, [IAS031B] ISBN:1-59623-776-7

Telecom providers such as Comcast Xfinity are trying to reach the mainstream market by offering a single channel for homeowners interested in purchasing and installing security, HVAC management, and lighting automation devices. They seek to provide both the local home management hardware as well as a software backend to enable integration of home automation and security devices with smartphones, tablets and other internet enabled devices. They represent a very promising opportunity to enable wider adoption of our zero-energy automated windows. Partnering with such mainstream home automation providers would provide a channel to a large percentage of the home automation market.

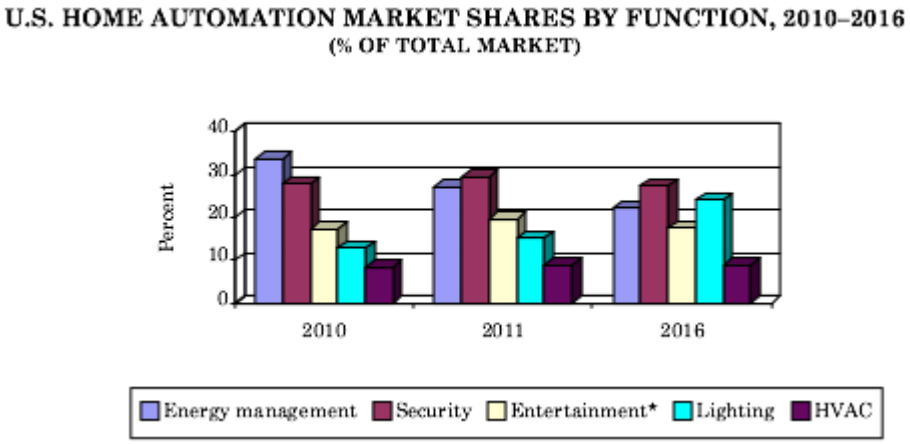


Figure 27: Breakdown of the US home automation market by function.

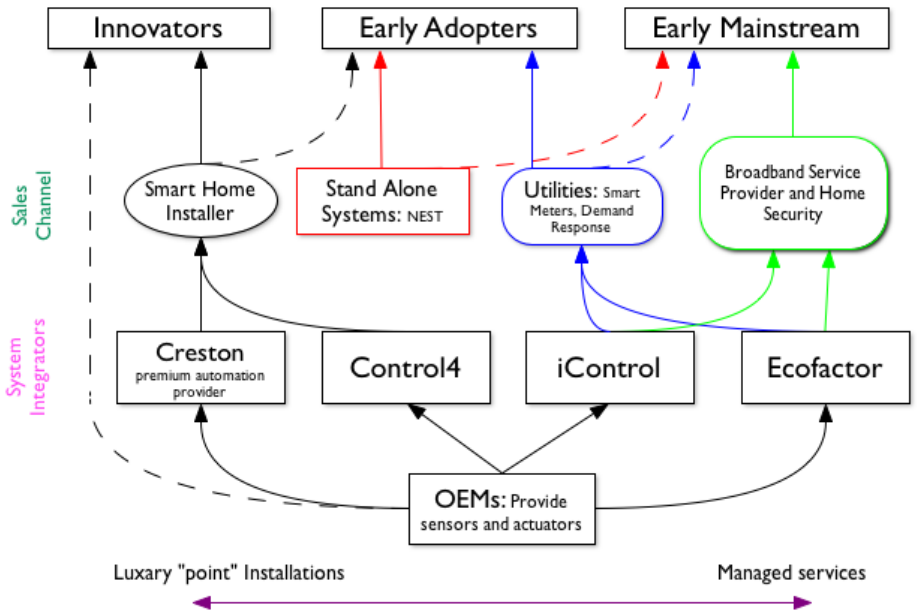


Figure 28:The different channels for home automation providers to reach different market segments. Solid lines represent primary channel and dashed lines represent secondary channel.

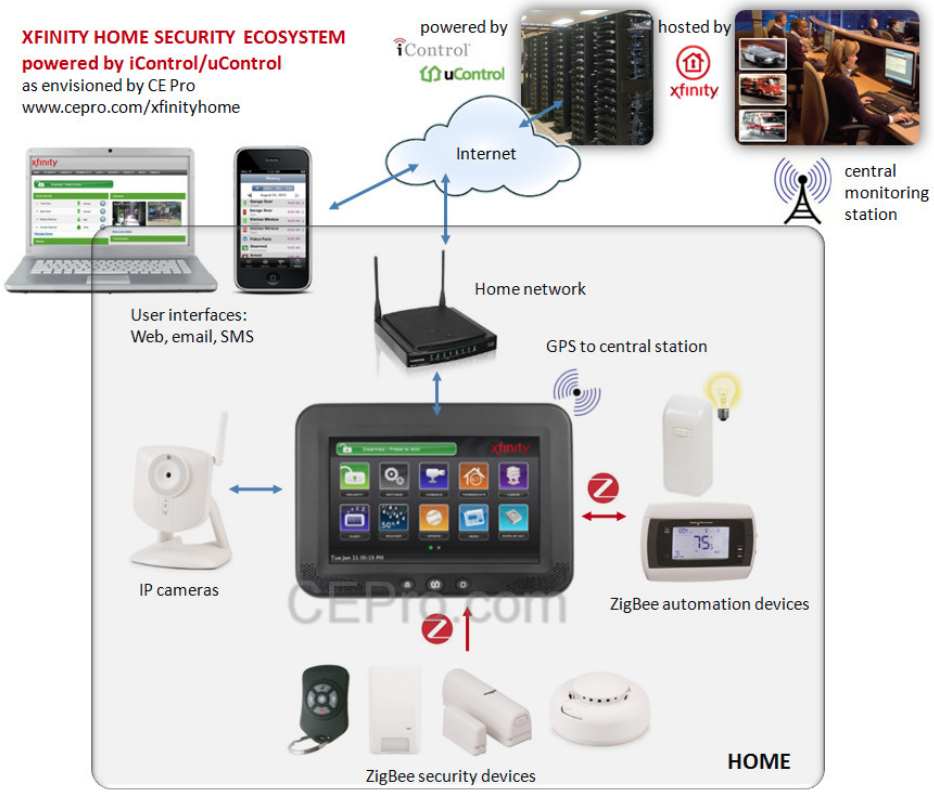


Figure 29: An overview of Comcast Xfinity home automation system, which seeks to provide an integrated home security and energy management system that will work with a portfolio of ZigBee enabled automation devices.

4.6.2. Protocols

The smart home market is currently dominated by two main protocols: ZigBee and Z-Wave. The ZigBee protocol has been adopted by many large home-automation-integrators and service providers, while Z-wave has become the de-facto standard for the do-it-yourself early adopters market. However, one of the key differentiating points between the two protocols is: the manner in which the ZigBee protocol is implemented by larger home-automation-system integrators does not lend itself to easy integration with OEM or stand-alone devices. This is because the larger system-integrators use encrypted, proprietary protocols on top of the open-source ZigBee layer in order to have more control over the ecosystem of home-automation devices that can integrate with their smart-home systems. However, the Z-wave alliance has maintained a much more open standard that is supported by upwards of 160 manufacturers worldwide and appears in a broad range of consumer and commercial products in the US, Europe and Asia. Z-wave is an inexpensive, open-source protocol, and the Z-Wave alliance has been driving the home integration market, which has been taking-off in the past year. An example of this

favorable market for Z-wave devices is Lowe's Iris Smart Hub home-automation-system controller, which can integrate a number of Z-wave devices and thus enables a more incremental DIY approach to home automation.

Feature	Z-Wave	ZigBee
Range	30.5 m	10-100 m
Data Rate	100 kbps	250 kbps
Frequency of Operation	900 Mhz	2.4 Ghz
Encryption	None	128 bit symmetric encryption

Table 13: A technical comparison of Z-Wave and ZigBee protocols

4.7. New Construction Residential Market

4.7.1. Decision making process

We analyzed the decision making process in the new construction residential windows market. For new building the decisions are taken at three different levels:

Architects need to design the building within the project budget, and costs are a very important component of the decision criteria. Architects also look at U-value (the insulation effectiveness) to ensure comfort of the building users. Finally, architects tend to have a specific view on how they want the building to look and prefer windows that stay in the same aesthetic.

Building contractors are also important decision makers as they make a final decision on the product choice when architects do not specify their preference. They are also the ones that directly handle window products. Building contractors care about the reliability and cost in particular. They look for products that will work properly at least for ten years after installation and tend to be very conservative in employing new technologies. Customers usually come to contractors when things do not work well, and contractors carry a significant reputational risk by installing unproven products. They tend to judge reliability of a product by their own past experience, word of mouth in the industry, recommendation of trustworthy builders, or often architect's recommendation.

Customers look for a payback period of five to seven years. An architect we interviewed indicated that if our technology has a payback period of five years or less, we will be able to essentially overcome the initial cost barrier. Seven years of payback period will still allow us to capture a significant portion of the market.

4.8. Retrofit Residential Market

4.8.1. Decision making process

In the retrofit residential market generally there are three key players in the decision making process

Homeowner: about 50% of the homeowners go to the retailers with enough knowledge on what type of windows they are looking for. In this case, installers and retailers do not have much influence in the final decision. Homeowners generally value aesthetics: the new windows should be aligned in design to their previous windows. They view the purchase of new windows as a long-term investment as homeowners typically live in the same house for 5-7 years. Therefore any technology that has a payback less than that time span is considered ready to be introduced into the market.

Contractors: about 30% of the homeowners rely on their contractors (with whom they might have a long term relationship) to advise them on which windows they should look at. Contractors prioritize windows that are readily available and easy to install. They are knowledgeable about the regular windows market but they generally do not pay attention to the energy performance and other features that a new product in the market may bring.

Retailer/Wholesaler: About 20% of the customers come to the retailers for advice without any prior knowledge. In this case, homeowners are not knowledgeable about the windows market and the retailers need to guide them through the different options. Based on our interviews, the retailers first try to understand the type of windows that the homeowners currently have (frame-materials/aesthetics) and how much they are willing to spend. Energy performance generally is not part of the conversation since most windows in the same price-range provide have the same energy performance.

4.8.2. Willingness to pay

An important factor in considering whether the product will be accepted in the mass market is price competition with traditional windows. While our product offers additional benefits, the product could successfully enter the market only if it demands a premium that consumers are willing to accept. Throughout this report, we call such a premium "willingness to pay" (WTP).

4.8.2.1. Samples and Demographics

To find out the distribution of WTP among homeowners, we conducted a survey with 208 homeowners in the US. Homeowners from California and Illinois were chosen because the two states represent moderate and cold climate zones, respectively, which offer a glimpse into how different levels of energy savings affect consumers' WTP. In each state, we segmented our respondents into two groups, the premium market (households with income above 75th percentile) and the mass market (households with income below 75th percentile). From our interviews with window retailers, these two groups typically purchase traditional windows at different price points. Therefore, our survey should provide a default window choice at respective price points to reflect such differences and find out their WTP's. This table summarizes the sample sizes and characteristics of each respondent group.

	Premium – California	Premium – Illinois	Mainstream – California	Mainstream – Illinois
Sample Size	52	52	52	52
Household Income Range	Above $100k	Above $95k	Below $100k	Below $95k
Home Ownership	Own Homes	Own Homes	Own Homes	Own Homes

Table 14: Sample sizes and characteristics of each respondent group

4.8.2.2. Methodology

Ideally, to accurately estimate WTP, we would hope to deploy experiments using the Becker, DeGroot and Marshak procedure (BDM), which requires the respondents to actually purchase the product to simulate consumer purchase behavior.[11] However, given the lack of actual products, we have deployed a combination of a direct survey, directly

[11] *Christoph Breidert, "Estimation of Willingness-to-Pay: Theory, Measurement, Application"*

asking respondents if they would purchase the product at a certain price point, and a method commonly used in BDM, presenting a tradeoff between a randomized price premium for our product and the respondent's default option.

For example, a mainstream market respondent in California would be told she needs to replace the windows in her home, at a cost of $21,000 for traditional windows. The respondent is then told about the benefits of using our product, including energy savings, security and privacy, health, and home automation. Then the respondent is asked if she would prefer the status quo, buying traditional windows, or paying a premium of $6,500 to upgrade to our product. This last tradeoff question is being repeated 4 times with different premium figures in a random sequence.

This approach has several benefits. First, instead of having the respondents suggest the highest price they are willing to pay, asking the respondents if they are willing to accept a given price is closer to the actual purchase environment. Second, compared to an increasing price or decreasing price approach, the random sequence approach prevents the respondents from building expectations of the price trend and therefore losing interest in subsequent questions.

Appendix II includes more sample questions used in the survey.

4.8.2.3. Results & Analysis

The survey results point to a tipping point of a $25 per square feet premium where consumers would start considering to upgrade to our product from regular double-paned windows, given all the energy, security and health benefits. The trend is also strikingly consistent across different income groups and climates. An important note is this premium includes the markup along the supply chain so readers need to be cautious when comparing this with cost. This result provides insights into how much we need to narrow the price gap in order to gain acceptance in the mainstream market.

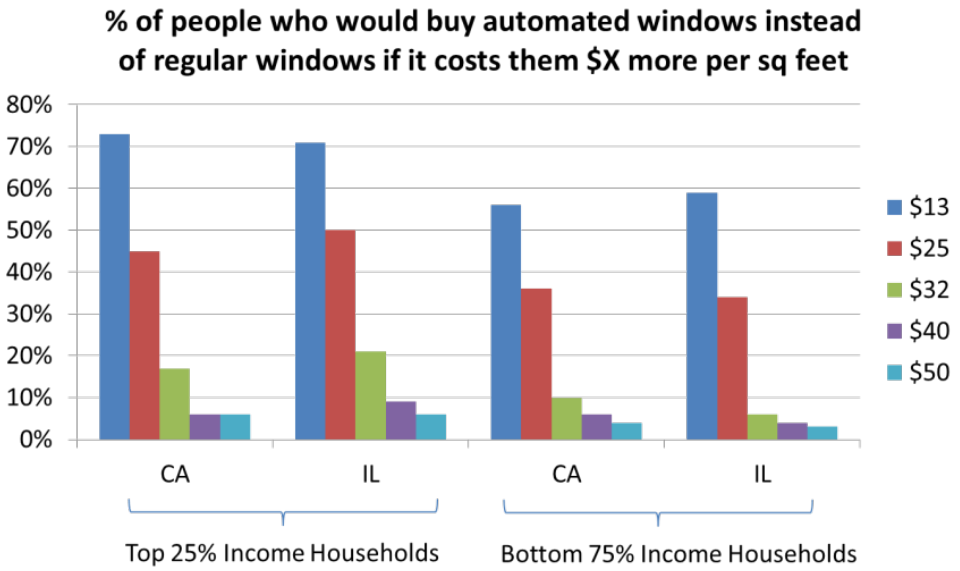


Figure 30: Willingness to Pay Survey Results – Upgrade Premium

Although consumers in Illinois were told they would save $250 per house per year compared to $140 per house per year in California, this piece of information does not seem to affect the WTP much. Instead, households in the high-income group have shown a high WTP to upgrade.

	Premium – California	Premium – Illinois	Mainstream – California	Mainstream – Illinois
Annual Energy Savings Per House[12]	$140	$250	$140	$250
Default Traditional Window Price Per House	$36,000	$36,000	$21,000	$21,000

Table 15: Willingness to Pay Survey Variables

Our survey also explores what features people value in our window. The results show that energy is predominantly the most valued feature, followed by health, security and entertainment. Even considering each features average ranking, energy still dominates, closely followed by security, health and entertainment.

Feature	Average Ranking (The lower the average ranking score, the more preferred the feature is)

[12] *Estimation of annual energy savings using figures from a previous LBNL study. Christian Kohler et al, "Performance Criteria for Residential Zero-Energy Windows" 2005*

Energy	1.84
Security	2.27
Health	2.50
Entertainment	3.49

Table 16: Willingness to Pay Survey Results – Feature Average Ranking

5. Final recommendations

5.1. Early Adopters

5.1.1. Product

From our interviews, customers who buy standalone motorized-shades as a component of their smart homes system already exist. To tap into this existing market, it is important that our product is compatible with the most popular smart home protocols. Also, these consumers are generally tech-savvy and energy conscious, and therefore promoting the energy saving features would be very important.

5.1.2. Price

Our product is price competitive with the current prevailing solution in the market: stand-alone motorized shades and wooden frame windows. It is important that the laboratory and manufacturing partners verify cost and markup assumptions. If price competitiveness is valid, this could facilitate entering the early adopters market.

5.1.3. Partnership

Since the laboratory plans to adopt an open-source approach, the pathway forward would be to share price analysis with major window manufacturers such as Pella and Anderson. We recommend that LBNL share that demand for zero-energy automated windows exists and that such a product is price competitive with existing solutions. In addition to traditional window manufacturers, the laboratory should also consider collaborating with smart home solution service providers such as Control4 and iControl to include automated windows into their offerings.

5.2. Mainstream Market

5.2.1. Product

From our survey, in addition to energy saving features, security and health are highly valued by prospective consumers in the mainstream market. The laboratory should seek partners to develop these capabilities further to extract more value from the automated windows.

5.2.2. Price

The significant gap between the current price-per-window paid by mainstream consumers and what our product could currently be sold for present a barrier to entry into the mainstream market. From our survey with 200 households, 30%- 50% of consumers are receptive to a $25 per square feet premium to upgrade from the most popular choice of windows in their income groups to our product. In other words, currently at $50 per square feet of premium, our product will need cost and value chain markup reduction to narrow the gap. Another avenue is to lobby for a "Super ENERGY STAR" status with the US Environmental Protection Agency and possibly a stronger Federal tax credit, which proved to be pivotal in bringing energy efficient windows to the mainstream market during the recession.

5.2.3. Partners

Utilities would be a key partner for the product. Thanks to regulatory requirements, many utilities are required to spend a portion of their budget on energy efficiency measures. In 2011, US utilities spent $5.9 billion on energy efficiency improvements. We should persuade utilities to include our product in its subsidy scheme because of our superior energy saving performance. Also, our product can also contribute to demand-response programs by reducing heating or cooling loads on event days. We strongly recommend that the lab explore strategies to integrate with existing demand-response programs.

Apart from utilities, we should also work with home security solution providers to incorporate our product into their security system offerings. Our product would be a unique addition to security alarms and automatic locks that are typically employed.

	Early Adopters	Mainstream Market
Product	• Develop smart home connectivity • Energy saving features a priority	• Develop security and health features
Price	• Currently price competitive • Validate cost and markup assumptions	• Narrow price gap to $25 per square feet • Lobby for "Super ENERGY STAR" status, and tax credits
Partnership	• Share price analysis with major traditional window manufacturers to show market acceptance for an integrated product	• Persuade utilities to include our product in demand response programs • Persuade utilities to include our

	• Partner with smart home solution providers	product in energy efficient rebate • Partner with home security service providers to include our product in offerings

Table 17: Summary of Final Recommendations

6. Interviews

Our team carried around 100 personal interviews to develop this report. The following chapter includes the most important interviews.

Personal Interview with Virginia Bello, Architect, Student at the Academy of Art University of San Francisco

Interviewer: Jose Marimon, Team Member 10/05/2013

LinkedIn: ww.linkedin.com/pub/virginia-bello/18/588/654/en
Website: none
Email: none
Phone: None
Source: Friend
Referrals: none

Keywords: architech, windows size

Summary:
Fitting the 5 inches depth of our window in an external wall should no be a problem. External wall usually are 9-10 inches, in CA we may find some below those values but rarely below 6-7 inches.

Details:

I explained Virginia the product. She appeared to be very interested in the product.
About value propositions:
- She said that the "comfort" side of the product will be more valuable to people in the Bay Area but not that much in other areas
- She said the the "energy" side will be more valuable to cold states and that in CA people will not pay for that.

With regard to the window depth she said that external wall generally are around 9-10 inches. In some houses in CA we may find depth below those values but we should not find anything below 5 inches.

She did not know how windows are actually physically change, she recommended me to talk to a construction company.

Personal Interview with David Ingber, Owner, Berkeley Share Company

Interviewer: Jose Marimon, Team Member 10/05/2013

LinkedIn:
Website: http://www.berkeleyshadeco.com
Location: 2039 University Ave, Berkeley
Email:
Phone:
Source: Web Research
Referrals: None

Keywords: Window shades

Summary:
Current price of "add-on" solution in the market = 400-460 usd (motor+blind+batteries+ controller) + 25 usd (installation).

Details:
Walked in Berkeley Shade Company and explained David about our project. Davis Ingber, the owner, was ok with replying some questions

They offer automatic shades of any size controlled with a wireless controller. He mentions that he sells some of them every year but there is not huge demand.

We talked about price for a 30 x 52 inches:

- Motor + batteries + Controller = 240 usd
- Blackout blind = 220 usd
- Other type of blind = 150 usd
- Installation = 25 usd/blind (if coming to install more than 3 blinds)

Personal Interview with Jason Lou, CEO, Enfocus

Interviewer: Jose Marimon, Team Member 09/21/2013

LinkedIn: None
Website: ww.**enfocus**.com/
Email: jason.lu@enfocuscorp.com
Phone: 408.800.6123
Source: Got the contact from Christian Hholer at LBNL
Referrals: None

Keywords: WIP research

Summary:
Commercial customers will be more interested in the economics and therefore the energy savings side while residential more in the comfort side.

Details:

Jason works at a company that sell a windows that produces electricity, reduces heat losses and increase comfort.

Key point of the conversation:
- Focus commercial and not residential because residential are more interested in the economic reasoning and 5 years payback period that the company claims
- He mentioned residential is more interested in the comfort side
- They initially created customers by doing direct marketing. Selected their target customers by understanding the kind of buildings that would be more interested in the electricity savings.
- All the manufacturing is outsourced because of money constrains

Jason will be happy to help us with the strategy to approach to customers to develop WTP. He is happy to coach us when we have the interview process and a brochure ready.

Personal Interview with Tom, Windows & Door Department at Home Depot

Interviewer: Jose Marimon, Team Member 11/02/2013

LinkedIn:
Website: http://www.homedepot.com
Email:
Phone:
Source:
Referrals:

Keywords: Windows Price, Home Depot Customers

Summary:
Home Depot usually spend $100/window with an average order of $4,000 (including installation). Customers are 50% homeowners, 50% constructors/installers.

Details:
Tom was very open and spent almost 30 min with me.
We talked about the type of customer Home Deport has. 50% of them are homeowners that need more guidelines when they make decisions. The other 50% are installers/constructors that are more knowledgeable and do not need that much support

Home Depot sales windows from $70 to $500. Installation is generally $250/window if Home Depot carries them.

The average order from a customer is around $2,000.

Energy performance is not a topic that is generally discussed since most of the windows has similar energy performance. Almost nobody goes for non low emissivity windows because they would save just around $7.

During the 30 min interview I just saw a couple of customers walking around the windows area, therefore making onsite interviews targeting 50-60 potential customers would take a lot of time.

Personal Interview with Robert, Seller at the Ashby Lumber Company

Interviewer: Jose Marimon, Team Member 11/02/2013

LinkedIn:
Website: http://www.ashbylumber.com/site/
Email:
Phone:
Source:
Referrals:

Keywords: Windows price, Ashby Lumber customers

Summary:
Ashby Lumber sells and install windows. The average windows price is $700 and 60% of their customers are homeowners while 40% to installer/constructors.

Details:
Robert is the main face to the customers. He has a little office in which he receives customers.

He told me that Ashby Lumber mainly sells Andresen windows and installs them. They may go to the customer's home to understand which is the best kind of window for their needs.

Most of the windows they sale are wooden windows. The average price per windows is $700 with a $300 installation cost. The average order is $5000.

60% of their customers are homeowners and they give them a customized budget offering different price alternatives within the same budget.

Personal Interview with Adam, Head of Windows Department at Lowes

Interviewer: Jose Marimon, Team Member 11/16/2013

LinkedIn:
Website: http://www.lowes.com
Email:
Phone:
Source:
Referrals:

Keywords: Integrated motorized Pella windows

Summary:
Adam expects that the cost of the Integrated Motorized Shade Pella windows will be around $800-1000 and will be released in 2014

Details:
I asked Adam about integrated motorized solutions and he told me that currently there is no product in the market with those features. Pella will be releasing an integrated motorized product in 2014. Adam did not have certainty on the price of this product but he expected it to be around $800-1000.

Personal Interview with Mary, Seller at the Lowes Shades Department

Interviewer: Jose Marimon, Team Member 11/23/2013

LinkedIn:
Website:

Email: http://www.lowes.com
Phone:
Source:
Referrals:

Keywords: Windows motorized shade

Summary:
The cost of the motorized shades add-on may vary from $300-500

Details:
I asked Mary about the different shades solutions that they sold at Lowes.
She share with me the following prices for motorized shade:
Not integrated Products (wood window - 400 usd + shade)
Serena
Batteries with IR remote control: 280 (shade) + 400 (window) = 680 usd
Batteries with RF remote control: 305 (shade) + 400 (window) = 705 usd
Bali
Batteries Solar powered: 428 (shade) + 400 (window) = 828 usd
Plug-in (transformer): 366 (shade) + 400 (window) = 766 usd
Allen & Roth by Vista Products
Battery: 460 (shade) + 400 (window) = 860 usd
Plug-in (transformer): 470 (shade) + 400 (window) = 870 usd

Personal Interview with Jose, Head of Wood Windows Warehouse

Interviewer: Jose Marimon, Team Member 11/02/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords:

Summary:
Wood Windows Warehouse designs, manufactures and install windows. The average windows price is $1000 and 80% of their customers are homeowners while 20% to installer/constructors.

Details:
Jose explained me the business model of the company. They generally make windows customized designs to the customers. They usually visit the customer house, make a design proposal with a budget. If the client accepts it, they manufacture the windows in the little facility they have in Berkeley. The average price of a window is $1000 and the installation is $600. I asked him about special features, like integrated shades, automation... and he mention that they also integrate them if the client asks for it.

Personal Interview with Eric Warm, Owner, Quality Windows and Doors

Interviewer: Nicole Johnson, Team Member 11/05/2013

LinkedIn:
Website:
Email:
Phone: (925) 484-1747
Source:
Referrals:

Keywords: WTP research

Summary:
CA might not be a good first target market, places back east care more about window performance!

Details:

Triple pane windows are overkill in most areas

- Title 24 regulates new construction - requires a certain level of energy efficiency
- More people do want energy efficiency windows as of lately...
- Current buzz word - fiber glass: panes can be painted any color (vinyl is generally white)
- Vinyl is the most common replacement window: plastic, pvc, energy efficiency
- Aluminum windows are cheaper but are not energy efficient at all
- "In CA, people don't care about windows" other states, especially on the east coast do
- History of window industry
    - wood is popular in our area, most people put these back in
    - 40s and 50s: steel made windows, now need to be replaced
    - 60s-70s: aluminum was popular
    - 70s-80s: vinyl became popular
- Andersen is popular back east
- Vinyl back east is better and more expensive (people are worried vinyl will melt in the hot climate of AZ
- Ohio -> extreme climate, need good window performance

Personal Interview with Jill Yastishak, Graduate Nursing Student, New York University

Interviewer: Nicole Johnson, Team Member 09/24/13

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: Hospitals, light-control, automation

Summary:
Unique VP for hospitals

Details: Is sunlight important for patients recovery?

- Yes, sunlight is an extremely important factor in recovery. She said it would speed up recovery rate but couldn't cite articles or anything

Anything in hospital policy about increasing sunlight for patients?

- No, if a patient doesn't want their blinds open, they don't have to be. Hospital staff just encourages it. And if the patients are able to go outside, hospital staff offers to take them out, but they can't make

Personal Interview with Jill Russell, Alameda Free Library

Interviewer: Nicole Johnson Team Member 9/19/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: Temperature regulation, book preservation

Summary:
Libraries fall into general category of Commercial Buildings, don't care so much about unique VP of preserving books

Details:
1. Heat regulation is an issue - it's usually very cold in one area of the library and hot in another
2. Director of the library said that there is nothing they could do about it
3. No books in the library are in direct sunlight
4. Have shades in the windows but they are not automatic

Jill gave me the pamphlet for the library which discuses the design aesthetics and various features of the building. The library is fairly new, it was opened on November 2, 2006. It is 47,500 square feet with seating provided for about 590 people. There are 75 pubic computers and wireless connectivity throughout the building. It cost $26.1 million to build ($15.5 million was from State Construction Bond). There is excellent natural lighting and the building is LEED Silver certified. The pamphlet says that "the building is energy efficient and utilizes green power from alternative energy sources, including wind and thermal through Alameda Municipal Power." It also specifically mentions that "Solar heat gain is controlled with sunshades and fritted glass." Additionally, "Solar gain and 'heat island effect' are reduced through the use of a light-colored ENERGY STAR coated roof that reflects heat absorption." However, Jill mentioned that these solar gain mitigations do not work because the upstairs floor (which has the roof directly over it) is always substantially

hotter than the first floor. The stark difference in temperature from floor to floor is noticeable even to patrons passing through.

Personal Interview with Ilaria Caputo, Alameda Free Library

Interviewer: Nicole Johnson, Team Member 9/19/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: Temperature regulation, book preservation

Summary:
Good tech solution but funding would be a major problem for a publicly funded library like this one

Details:

1. heat regulation is a definite problem
2. light is a definite threat to books - they have to make sure the books are out of direct sunlight
3. believes the problem with implementing a technology like ours would be funding

Personal Interview with Ramona Martinez, Boalt Library

Interviewer: Nicole Johnson, Team Member 9/14/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords:

Summary:
Could be a good potential niche market, don't usually put books in direct sunlight; keep books underground for that reason

Details:

The Seattle Public Library is all glass. Ramona recommends that we do some research on how they deal with being all glass and said she thinks they use windows with a special coating. Light is a big concern and it does damage the books so they don't usually put books in direct sunlight. Another concern is that books are heavy so some are stored underground. In Boalt's library there are automatic shades (not where the books are) but they don't currently work.

Personal Interview with Christina Winstrom, UC Berkeley Greenhouse Manager

Interviewer: Nicole Johnson, Team Member 10/07/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: greenhouses

Summary: UC Berkeley Greenhouses are ready for prototypes

Details: Having a self-shading window would help on so many levels, from energy savings to plant health. Definitely interested in prototype trials, and we are welcome to check out Cal's greenhouses to see the types of glass currently installed.

Personal Interview with Linden Scheider, Sr. Nursery Tech and Instructional Support Plant Collector, Department of Integrative Biology at UC Berkeley

Interviewer: Nicole Johnson, Team Member 10/07/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords:

Summary:
Greenhouse industry is already looking into smart windows!

Details:

The smart window is something the nursery/greenhouse industry is most definitely interested in and already looking in to. I will give you a few helpful resources here which I think will prove very fruitful in the information they provide.

Linden gave me some great resources to check into if we decide to further explore greenhouses

"1. AERGC http://www.aergc.org/ This forum is great! I would suggest you subscribe to the email forum, and send an email out to the members with the information you provided to me. You will get many opinions from the top professionals at schools around the nation.

2. Tina Wistrom (cwistrom@berkeley.edu) - She is the Greenhouse Manager here at Cal's largest greenhouse facility - Oxford Facilities Unit over between Oxford and Walnut off of Hearst. They have about 20,000 sq ft of greenhouses. Maybe she would be open to proto type trials, but will generally provide you with good info/feedback as well.

3. Four Winds Growers- This is a personal contact of mine and a really awesome family business. These guys produce all of the dwarf citrus trees in northern California in addition to a variety of other fruit trees for the home gardener (you will see their plants at Home

Depot, Lowes etc.). A while back they had mentioned they were partnering with UC Santa Cruz to possibly test some prototypes of redhouses- electricity generating greenhouses (see http://ucscsustainability.blogspot.com/2013/03/research-focuses-on-redhouses-and-solar.html). "

Personal Interview with Marisa Hanson, Summer Intern, Hammer Museum

Interviewer: Nicole Johnson, Team Member 9/24/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords:

Summary:
Lighting ambiance trumps energy efficiency but heating and cooling costs are significant for museums

Details:

Marisa worked at the Hammer Museum this summer identifying energy efficiency opportunities to implement. They were particularly interested in lighting options for different spaces throughout the museum and some offices, so that was what a majority of her focus was on.

"Some thoughts on protecting the art:
* You are correct that direct sunlight and excessive heat can damage many types of art. Hammer was under contractual obligation to keep the spaces that house art within very specific temperature and humidity ranges. I imagine this is the case for most museums. Because of this, art that wasn't on display was kept in windowless rooms that were heavily temperature and humidity controlled and monitored. Because windows present such an easy opportunity for air leaks which would compromise the efforts of controlling the climate, I'm guessing most museums store art in windowless rooms. However, calling around to various museums can give you a much better idea of typical practices.
* I learned quite quickly how important lighting in gallery spaces is to many stakeholders within a museum (curators, preparators, artists...) This will likely take precedence over any energy efficiency ambitions. I'm not sure if you were considering the use of these

smart windows in gallery space, but speaking for the Hammer, there were no windows in any of the gallery spaces. Again, this is because the lighting techniques and preferences are so specific, that any outside light introducing variability in the appearance of the art is strictly avoided.

* Having said that heating and cooling costs are quite significant for museums, especially in warmer, drier climates. If there is opportunity to implement energy saving measures, most would jump at the chance.....as long as there is no negative (or even perceived negative) effect on the appearance of the art."

Personal Interview with Ganesh Iyer, Marketing Professor, Haas

Interviewer: Louis Li, Team Member 10/18/2013

LinkedIn:
Website:
Email:giyer@haas.berkeley.edu
Phone: (510) 643-4328
Source:
Referrals:

Keywords:

Summary:
Discussed approaches to find willingness to pay for integrated windows.

Details:
I discussed with Ganesh approaches to find out willingness to pay from consumers and asked for his opinions on our sample survey.

- Ganesh suggested we collect information about respondents' home situation and try quickly estimate energy savings based on the situation so we can get a more realistic result.
- Ganesh believed it's too early for conjoint analysis. Instead we should first try understand if respondents like the smart features, and the reason behind.
- At this stage, a sample size of 50 people would be reasonable, although ideally more.

Personal Interview with David Riemer, Executive in Residence, Ex-Yahoo

Interviewer: Louis Li, Team Member 10/17/2013

LinkedIn:
Website:
Email: davidariemer@yahoo.com
Phone:
Source:
Referrals:

Keywords:

Summary:
Discussed approaches to find willingness to pay for integrated windows.

Details:
We discussed with David approaches to find out willingness to pay from consumers and asked for his opinions on our sample survey.

- David emphasized it's important to interview window dealers who have extensive experience dealing with customers. He also thinks it's important to understand what the dealers' concerns would be if they need to carry this product.
- David likes the survey format (BDM) which asks respondents to choose between the window and cash value. He suggested we modify the survey such that we test the value of the premium over a regular window rather than the total value of the window.
- David thinks it's too early to use conjoint analysis to test relative importance of non-energy features. All the features are very new to respondents. We should focus on getting feedbacks what features will be useful.

Personal Interview with Matt Ganser, Director of Impact, Carbon Lighthouse

Interviewer: Louis Li, Team Member 10/05/2013

LinkedIn:
Website:
Email: emma@carbonlighthouse.com
Phone:
Source:
Referrals:

Keywords:

Summary:
Matt shared more of the implementation aspect of window and shading retrofit.

Details:
Carbon Lighthouse is an energy retrofit service firm based in California. This is a follow up interview with Matt's colleague, Emma Bassein, Director of Impact.

From their team's previous assessments, economically it is not easy to retrofit windows. The first hurdle is the owners need to empty the space for a few days, which means disrupting the tenants, increased costs by placing tenants in a temporary office. To minimize this impact, the Empire State Building emptied one floor for a few months as a temporary "factory" to take down the windows overnight, add one extra pane (so the windows become double-paned) and place it back. This is however an expensive exercise, which their team estimated the payback was over 15 years, compared to 5 years which most building owners require.

The idea of add-on automatic shading sounds more feasible. One cautionary note is, while HVAC energy could be saved using shading, lighting energy is hard to save in this case. To save on lighting, buildings also need to retrofit their lights to dimmable lights, which requires a different type of ballasts, photo-sensors and control/connectivity devices to enable automatic adjustments of lights. This kind of investment typically requires about 10 years of payback.

Personal Interview with Johnson Kwok, Engineer, Cathay Pacific Airways

Interviewer: Louis Li, Team Member 09/27/2013

LinkedIn:
Website:
Email: johnson_kwok@cathaypacific.com
Phone:
Source:
Referrals:

Keywords:

Summary:
Safety a top concern for aircraft window decisions.

Details:
Electrochromic glass is being used on the latest model of Boeing aircraft Dreamliner. Launching customers ANA have opted for the windows. It seems to offer maintenance cost advantage because the movable part of the shades is removed.

Although Cathay currently does not use Dreamliner which features electrochromics glass windows, Cathay is considering use of smart glass on its new A350 purchase which offers auto dimming, solar reflectance, and reduced glare. Cathay currently does not track energy consumption for temperature control inside the aircraft.

In Cathay, window purchase decision for aircraft is typically driven by engineers. The top concern is safety. Window materials would need to go through safety tests like impact and pressure. An aircraft with a slight crack would be grounded for maintenance for days and cause hundreds of thousands of lost revenue. If an algorithm is being used, it will likely be considered a software and need to go through robust tests as well to make sure it would not corrupt the aircraft's core software systems. The regulatory process is typically capital intensive and lengthy.

Personal Interview with Jasmine Hui, Manager - A350 Implementation, Cathay Pacific Airways

Interviewer: Louis Li, Team Member 09/30/2013

LinkedIn:
Website:
Email: jasmine_li@cathaypacific.com
Phone:
Source:
Referrals:

Keywords:

Summary:
Operational concerns for using motorized shading on planes

Details:
While passengers typically complain about discomfort with temperature, it is tough to deploy automated shading on aircraft to regulate temperature on long haul flights. On long haul flights, passengers usually have a tough time sleeping so flight attendants would usually ask passengers to close all the window shades during flights so passengers can choose when they sleep. There could be minor convenience benefits. For example, some passengers might fall asleep while leaving the shades open. The light through the windows could be disturbing for other passengers. Flight attendants can then close the shades without waking the passengers up.

This application however could be possible for short haul flights during daytime. Passengers typically complain it's too hot or too cold so an algorithm could help regulate that. Individual control for passengers would still be useful because some would prefer to read with natural light and some prefer to sleep during flights.

Cathay would be wary about using the current smart glass technology on planes because it is not 100% transparent yet.

Personal Interview with Allison Harvey, Director, Golden Bear Sleep Research Clinic

Interviewer: Louis Li, Team Member 09/27/2013

LinkedIn:
Website:
Email: aharvey@berkeley.edu
Phone:
Source:
Referrals:

Keywords:

Summary:
Sleep research validates value of automated shading to sleep disorder patients.

Details:
Louis: The technology is primarily designed to save building cooling and heating technology, but my project also explores other market applications. From my research, many people who live in areas with seasonal extended daylight eg Alaska, experience disrupted circadian rhythm and therefore sleep problems. Our idea is if the technology can control the amount of sunlight and its timing throughout Summer to imitate a daytime schedule similar to other parts of the world, it might be able to alleviate sleep problems in places like Alaska.

Prof Harvey: This is a terrific idea. Yes, light cues go from the retina through to the SCN through to the Pineal gland and in that way have a profound influence on sleep and wake. So any manipulation of light/dark is a good thing.

Personal Interview with Berkeley Design Center, Manager, Berkeley Design Center

Interviewer: Bin Chen & Achintya Madduri, Team Member 11/04/2013

LinkedIn:
Website: http://www.berkeleydesigncenter.com/
Email: info@berkeleydesigncenter.com
Phone:
Source: Online search
Referrals:

Summary:
The early adopters of our products should be those tech sensitive people (online, well-educated, conscious about energy efficiency) 2. The market share of triple pane windows is <10%, really small.

Details:
Thoughts on our product:

- It's really correspond to the type of climate. (like in CA, it has little market, coz the climate is so mild, the energy saving of product almost has no big difference than other energy star windows; However in those cold climate, it might have larger market)
- If the existing double pane energy star windows is around $450, and our product is around $550 with extra features(automated shading etc.) he might consider to use our product

For the triple pane windows:

- Even though the triple pane windows has been in the market, but for them (both as architects, design professions and contractors) they never use triple pane windows in their projects.
    - Because the higher cost of the triple pane windows
    - The energy saving from triple pane in CA is not so effective

The process of people thinking remodel their house:

- First submit the plan to the design review people for approve(planning commission, city council)

- Contractors/design professions ask customers questions--> estimate the cost of the remodeling options-->let the customers decide which option they are choosing

Personal Interview with CHIP SENNA, Manager, V&W patio door & window Co., INC

Interviewer: Bin Chen & Achintya Madduri, Team Member 11/04/2013

LinkedIn:
Website: www.vandwpatiodoor.com
Email:
Phone:
Source:
Referrals:

Detail:

1. Window esthetics is the first factor when customers choose the windows. 2.Tax credits has huge impact on stimulating the market of energy efficient windows. 3. The cost of the windows itself and the labor are roughly the same 4. Visual transmissivity is one of the biggest concern for customers to choose the windows, since not only they want energy savings, they also want natural daylight.
Citation:

- Existing energy efficiency windows(All of them are Energy Star windows)
  - 2~72% Double pane windows with 2 layers of low-e coatings, argon gas
  - 3~66% Double pane windows with 3 layers of low-e coatings, argon gas
  - Visual Transmissivity goes down with more layers of low-e coatings, which is an obstacle for energy efficient windows-->customers concern about their impact on daylight
  - Triple pane windows
    - Heavy
    - Put too much stress on window fringe, adding extra labor cost (lengthening the window sill to hold the extra layer)
    - <10% of the customers would buy it.
    - The price of the triple pane windows are generally 35% (around $135 per unit) more than the double pane(around $100 per unit)
- Their customer
  - Most of them are home owners, who are going to retrofit their windows
    - For those customers, the most common window they choose to do the replacement is 2~72%

  - There's few new home customers (really rare especially in Berkeley)
- Customers decision making process
  - They have a hard fixed budget for retrofitting the windows.
  - They would pay more to try the new products or energy efficient windows with extra features, unless they understand why they are paying more for?
  - The window esthetics comes as the first consideration when choosing the windows, instead of Energy Efficiency
    - Vinyl windows are not so popular in the retrofitting markets, because it has only two colors, which might not match the existing windows.
    - On the contrary, the wood windows, because it could be painted whichever color the customers want, are more popular
    - City codes has some requirement for home owners to replace the windows, such as the style should match the other windows etc., which to some extent stimulate wood windows sales.
  - When customers decide to replace their windows 1. they go online to check out the information (like energy star windows etc.) 2. they go to home depot to check the price 3. they compare the price at home depot with the window stores (like V&W) consult the stores, which provide specialized knowledge/expertise, but the price is a little bit higher than home depot 3. Because of this, most of the customers end up with those window stores, rather than home depot.
- The reason why people replace the windows
  - The old windows are not functioning well, like leakage…
  - The old windows are old fashion double hung windows
  - Some tech sensitive customers (well educated about energy efficiency) are pursuing the new energy efficient products.
- The price of the windows
  - For a typical 4 bedrooms house
  - Using the vinyl windows-->$27,00 + labor (roughly the same $27,00)
  - Using the wood windows-->$45,00 + labor (roughly the same $45,00)
  - For the double pane energy star window
    - $65~70 with fiberglass framing
    - $100 with wood framing
    - $55 with vinyl framing
- Thoughts about our product
  - Concerns with the shadings
    - The customers should be super clear about how this works, like the shading device could be easily replaced, the inner layer of the glass is not sealed, could be open.
    - Dust is a highly tough issue from a long time perspective

- Tax credits is the largest and most effective incentives for customers to buy energy efficient windows
  - The energy star rebates, which is roughly $200 is not really a good incentives, compared to the $5000 cost for replacing the windows
  - But when the government have tax credits for energy star windows, which will give $3500 tax credits, compared to $5,000 ,has very effective influence on customers decision.
- Building codes (like title 24 in CA) has impact on customers to choose energy efficient windows
  - For example, according to title24, home owners may spend more money on buying energy efficient windows, so that they could spend less on the framing of the house (like instead of using 2x6 stud, using 2x4 stud, which will save more money, compared to the extra expense on windows)

Personal Interview with Qi Li, Former Architect, Nihon Sekkei, Inc.

Interviewer: Bin Chen, Team Member 12/02/2013

LinkedIn:
Website:
Email: liqiisagreatman@berkeley.edu
Phone:
Source: Architecture graduate students
Referrals:

Summary:
There's limited market for hotels, since the shading will be considered as one of the building element. Hence the automated shading part of our windows, doesn't have a high VP in the hotel market.

Detail:
Qi Li was in this Architecture Firm as an Architect, who had experiences designing hotels.
1. What's the normal decision making process for architects who design hotels to choose windows products?
After figuring out the window-wall-ratio of the project, the area of the windows could be calculated. Then they will design the size and number of window units based on the aesthetics and function of the windows.
Usually they will consider the type of window framing materials first, like the color, texture. Then they will choose the specific window types and products from the windows companies, who they have had some cooperation before
2. Will you consider energy efficiency when designing hotels?
It really depends on the budget of the project. Like when they are designing certain five-star hotel and they have really high budget. Then they will definitely choosing the high energy efficient windows product.
The final decision maker is the building owner, but he will listen to the recommendations from the contractor and the architects.
To be frank, the savings from using energy efficient windows is a very small portion compared to the whole cost of construction. The payback might be long.
3. How do you choose shading products for windows? Will you make recommendations when design the buildings, like which windows should use shades?

For the living rooms, they usually extend the floor panel to be the overhang of the windows. It will save a lot of maintenance cost compared to add the exterior shading device later on.
4. Will you choose a product, which has four layers, with integrated shading device in it?
I will consider, only if the windows style match the design of the building. I'll definitely won't choose a specific type of windows to do my design.
Besides, the aesthetics, the initial cost and the maintenance cost are two significant factors I'm thinking.

Personal Interview with David Campbell, Former Architect, WJE- Wiss,Janney, Elstner Associates,Inc.

Interviewer: Bin Chen, Team Member 12/02/2013

LinkedIn:
Website:
Email: dccampbell@berkeley.edu
Phone:
Source:
Referrals:

Summary:
The architects don't really care too much of windows when they design the buildings, since it's really a small portion in terms of the whole building. They consider the energy efficiency, but only to meet the requirements of the building codes. So if we want to shorten the time of our product to market, suggestions would be increase the requirements of building codes.

Detail:
1. For residential buildings, what's the decision making process of architects to choose windows.

David: For local architects, when they design residential buildings, the firm usually has some fixed partnership with certain company.

Like the project he has done before, the firm is partner up with Jeld-Wen Inc. Every time when they design the windows, they will just choose different products of Jeld-Wen based on different functional requirements of the windows.

2. Is energy efficiency one of the concern when they choose which type of windows they are using?

David: They do. But only limited to the requirements from Title 24, regarding the R value, the SHGC etc. But definitely not the first concern. Usually aesthetics and function of the windows comes first, like in order to maximize the natural ventilation, they usually choose casement and awning.

Personal Interview with with Hsiu Wei Chang, Former Project Manager, Hsieh Ying-Chun and Atelier-3 (Taiwan)

Interviewer: Bin Chen, Team Member 12/03/2013

LinkedIn:
Website:
Email: crazydrumer10@berkeley.edu
Phone:
Source:
Referrals:

Summary:
Architects prefer wood framing windows with high energy efficiency, even though the cost might be a little higher; for the new construction of residential building in post-disaster phase, there's little market of our product.

Detail:

- The architect will decide the type of windows in the architectural drawings.(like whether to use single pane or double pane).
- For residential design, the architects won't specify whether the interior shadings to be used. It totally depends on the building users. However, they will integrate their design with some exterior shadings.
- Thoughts about our product: a) the maintenance cost b) the reliability of the automation system. Is there a backup choice if the automated control breaks down?
- When choosing the windows types, architects care a lot about the window framing materials. For example, they like wood framing windows, because wood framing materials give them more power to integrate with the aesthetics of the design. However, at least in Taiwan, there's few wood framing windows that are energy efficient. So our product would be very compelling for architects.
- He mainly has done a lot of projects about residential buildings in post-disaster phase. For those projects, there's very limited budget, therefore few architects will really use energy efficient windows, because they are really costly.

Personal Interview with Kevin Weekly, Graduate Student, Electrical Engineering, UC Berkeley

Interviewer: Achintya Madduri, Team Member 9/05/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: Wireless protocols

Summary:
This was a technically focused interview with a student in Prof. Costas Spanos' group who does deployments of sensors in a building environment. The motivation behind the interview was to get an understanding of the various protocols in the home automation protocols space.

Details:
- Zigbee is the prevalent protocol in the building sensor area.
- There can be a centralized computer in closet even for office spaces which integrates the sensors and then runs through "backnet" IP protocols to be controlled by building manager.
- Networks need to be encrypted to ensure security against hostile "agents"
- Strong preference from building managers to have legacy protocols supported (Backnet, RJ-485, etc). Managers can be ambivalent to allowing control of environment by the occupants.
- Zigbee protocol more suited to sensors rather than actuators. To control a single window the signal might have to be broadcast across whole network.

Kevin's personal thoughts:
- Has had bad experiences with Zigbee. Connectivity and packet drops can be a problem. It only has a single channel so bandwidht issues can be limiting. There is no buffering of data with Zigbee, so if network goes down then all sensor data can be lost. Not sure if this applies to us though.
- For in-home Kevin suggests that Bluetooth might be a good protocol since it is short range and only one-to-one from a device pairing perspective. To address multiple windows, it

would require the controller to move physically from window-to-window. However, bluetooth has the benefit of being an already integrated protocol into most Internet enabled personal consumer electronics.

Phone Call with Hood Branco Innovations San Francisco Owner, Smart-Home/Building Installer & Dealer for Control4, Hood Branco Innovations

Interviewer: Achintya Madduri, Team Member 10/22/2013

LinkedIn:
Website: www.hb-innovations.com
Email:
Phone:
Source:
Referrals:

Keywords: Smart-home market, wireless protocols

Summary:
Smart-home installer who was very knowledgeable about the past and future trends of the smart-home market. Also had recommendations on wireless protocols.

Details
Q: What are the existing solutions in the adjustable SGHC space?
A: We already have existing solutions for integrated systems. In our installations we use sensors, automated windows and control systems to have independent solar zones, solar-tracking, and light-sensing based solar-gain. We are large-scale installers and system integrators, we already have products that integrate features that you have mentioned.

Q: What about the retrofit market?
A: We don't play in the retrofit market, Q-motion is an existing solution for automated window treatments in the retrofit market. They have battery-based motorized blinds for the retrofit market.

Q: Protocols: ZigBee vs Z-wave.
A: Z-wave is inexpensive, open-source protocol. Larger companies like Control4 use Zigbee, but they make it a propriety protocol. Z-wave is aimed at the cheaper/do-it-yourself market. Z-wave has been pushing the home integration market and in the past year this has been taking off.

Q: Details about the Home-automation market.

A: Avenues are thru: Home Depot, Lowes, Amazon (big). Staples and Lowes (Iris) will have OEM controllers that will charge a certain amount for cloud services and in theory incorporate any Z-wave device.

Q: Suggestions?
A: Look at Z-wave alliance web-page and see what are existing products.

Key Insights:
We already have solutions that have the functionality you have described for institutions and large-scale buildings. Zigbee is not truly open-source in implementation since large companies are "using" Zigbee but modifying it with proprietary protocols and encryptions such that no-one else can play with them. You should look at the Z-wave alliance page. Z-wave is bringing accelerated development to the home automation market! Z-wave products are proliferating like wildfire!

Phone Call with John Gorman, Owner, Save Energy Company

Interviewer: Achintya Madduri, Team Member 11/04/2013

LinkedIn:
Website: www.saveenergyco.com
Email:
Phone:
Source:
Referrals:

Keywords: residential windows market

Summary:
Many factors influence customer decision process, energy-efficiency is one of them but it is 3rd or 4th. The typical order for them is a few $1000. Almost all windows sold are "energy efficient" windows. The major decision makers are typically women. Triple-pane windows exist but are small percentage of market. The breakdown between labor and capital costs is roughly 50-50. The main reasons for replacing windows are mainly comfort issues: customers either feel too-cold or too-hot. Most customers are not knowledgeable about ENERGY STAR and the type of benefits that it can offer. However, price is a major decision point.

Suggestion:
The Biggest changes in window technology is in the type of glass. Cardinal glass is a glass-manufacturer and a possible follow-up interview target.

Personal Interview with Arundhati Jayarao, Homeowner, Washington DC

Interviewer: Achintya Madduri, Team Member 11/28/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: residential windows market, customer interview

Summary:
Interview of a home-owner who lives in Washington DC area with questions from our online survey in order to test out the survey questions in person.

Details:
Female home-owner, middle-income household, not tech-savvy but very energy conscious.

Survey Answers:
- Energy savings most important.
- Security and Home automation features not a huge draw.
- "I already sleep with my blinds open so am not sure if the alarm feature is that important to me"
- Most important feature is payback of the energy savings from the new windows. If payback is in the 10-year range then there is some interest. Otherwise, not as interested.
- Also interested if it increases the home value.
- Potential interest in rebates from Utility/Demand-Response programs.

Personal Interview with Paula Lipka, Graduate Student, UC Berkeley Industrial Engineering and Operations Research

Interviewer: Achintya Madduri, Team Member 12/02/2013

LinkedIn:
Website:
Email:
Phone:
Source:
Referrals:

Keywords: Utilities, Demand-response

Summary:
Paula is a graduate student in the IEOR group of UC Berkeley. She studies the utility-markets and was able to give some insights on demand-response programs and the viability of our automated windows for demand-response.

Details:
- Demand response happens on multiple time scales.
- Reducing peak demand could be very useful.
- Aggregators might be able to give homeowners a contract to bundle and sell the shade control a XX kW load to the utility/system-operator.
- Marginal prices can go very high, up to 100x normal prices of electricity. So the ability to play within this market can have a substantial monetary benefit for the aggregators/home-owners.
- Important to understand the dynamics of the shades on room temperature and how they reduce energy use in the home. This needs to be quantified and then it should be possible to participate in demand-response programs.

Personal Interview with Bev Alexander, Instructor, C2M, Former PG&E Demand Response Employee

Interviewer: Achintya Madduri, Team Member 9/19/2013

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Phone:
Source:
Referrals:

Keywords: Utilities, Demand-response

Summary:
Bev provided a quick overview of residential scale demand-response from the perspective of someone who worked for PG&E and in fact was part of the demand-response team there. There are multiple layers/programs from the customers' perspective starting with rate management, critical peak pricing, AC cycling, and Aggregator services. The key metrics that a utility is interested in are: # of customers, # of MW, # kWhrs and # of Days that are signed up in the demand response. Of committed amount to demand response of often only 50% was delivered. So PG&E has a high demand for more reliable demand response.

Takeaway questions:
1. How quickly can we respond to a demand-response event?
2. What is the market size?
3. Could we provide a more reliable service by having control of the blinds? For instance can we get closer to 75% delivered by virtue of shutting down blinds and reducing the heat into those households that are actually supposed to participate in the demand response program?

Key Insights:
1. Only 50% of committed demand response is actually delivered. 2. PG&E has very aggressive targets to sign on more people into the demand response program.

7. Appendixes

7.1. Appendix I

Explanations of Applications

1. Energy Efficiency for Buildings - As explained, zero-energy windows can reduce energy use in a building by up to 23%.
2. Automatic Daylight Control for Buildings - in addition to energy efficiency, occupants also benefit from automatic shading control that regulate the amount of daylight such that it is optimal for workplace or home comfort.
3. Demand Response - by closing building shades on hot days, utilities can reduce peak energy consumption through demand response programs, and therefore reduce the need to build new power plants.
4. Sleep Cycle Regulation - Research has found that excessive or insufficient daylight exposure affects sleep quality.[13] This is particularly evident in areas like Alaska which experience extreme daylight cycles.
5. Remote Shading Control for Mobility Challenged Individuals - A patient room providing good outdoor views and daylighting can increase patient well-being: a psychological state resulting in reduced stress and anxiety, lower blood pressure, improved post-operative recovery, reduced need for pain medication, and shorter hospital stays.[14] However, often patients are unwell to operate shades throughout the day so the shades often end up being closed for a long period of time. Connectivity of our product provides remote shading control and automatic shading program.
6. Trains - the large number of windows on trains means huge amount of heat is lost or gained through windows. Changing climate along the route also demands stronger automatic regulation.
7. Planes - similar to trains, but typically faces higher regulatory and operational barriers.
8. Sleep Cycle Regulation for Astronauts - While sleep cycle is a significant problem among astronauts, there could be significant technical barriers deploying integrated shades in space stations.[15]
9. Asset Preservation in Libraries - Originally, our value proposition related to adding in sun-protection for the books in the library so that space can be maximized and book shelves could be put closer to windows. However, through interviews it was found that libraries fit more into the category of a commercial building in terms of

[13] *http://articles.ktuu.com/2010-03-17/circadian-rhythm_24128484*

[14] *http://www.betterbricks.com/graphics/assets/documents/Daylighting_patient_rooms_brochure_final.pdf*

[15] *http://science.nasa.gov/science-news/science-at-nasa/2005/03jun_naps/*

what they care about. They care about temperature regulation more so than the unique value proposition of using our window to protect their books from the sunlight.

10. Asset Preservation in Museums/ Art Galleries – These places are about energy efficiency, but care more about how the exhibits are lit. Most of the displays are in areas where there are no windows the amount of light needs to be precisely controlled.
11. Stadiums - Not a large market but our windows do provide a unique opportunity for stadiums. Closed-in stadiums are becoming more popular these days. For the world cup in Qatar they are set to build 9 number of indoor, air-conditioned stadiums. These stadiums spend a very large amount of money on heating/cooling costs. Houston stadium uses more energy each year than the entire city of Santa Monica because of its air conditioning needs. Since stadiums are not used that often, our automated windows can be installed on the roof and the shades could be programmed to help control the internal temperature and therefore reduce heating and cooling costs. Could be a potential niche market in the long-run.
13. Light and temperature control for greenhouses – Light and heat levels are extremely important for plant growth. Having a shade that would automatically control the light and heat inside the greenhouse would relieve greenhouses managers of a great deal of what is currently manual labor.

7.2. Appendix II

Willingness to Pay (WTP) Survey Sample Questions for Mainstream Market Respondents in California

7.2.1. Scenario Information

Let's assume you have decided to remodel all the windows in your house. The windows you have chosen cost you $36,000 in total for the whole house (shades and installation included). You have just placed an order for it.

The window dealer tells you that you have a chance to upgrade to the latest energy-efficient smart windows. The state-of-art, smart windows have some new capabilities:

a) Three layers of highly insulating glasses

b) Motorized window shades which would open and close automatically according to your preference and weather condition

7.2.2. Estimating Relative Values of Different Features

The smart windows provide these major benefits. Which feature is the most important to you? (1 = most important; 4 = least important) (These options are randomized in sequence to prevent bias)

a) Security & Privacy – You can preset programs to close shades during hours you are away for work. Forgot to close your blinds while you are traveling? Remotely close your blinds with your smartphone.

b) Home Automation - Your windows are connected with the rest of your home appliances. For example, with one click, your living room enters theater mode: Your movie starts, lights dim, and shades close.

c) Energy Saving – The smart windows will save you $140/year in energy.

d) Health – Research has found natural light exposure affects your sleep quality and mood. For example, you can connect the shades with your alarm clock so that you can wake up with natural light, and make sure it's all dark when you sleep. The strong sound insulation also gives you a quiet sleep environment.

7.2.3. Estimating WTP

Now you need to make a decision: would you choose to…

a) Stick to the double-paned windows that you have ordered. (ie total cost $36,000)

b) Add another $6,500 (ie total cost $42,500) to upgrade to the smart windows

7.2.4. Variables for Different Groups of Respondents

	Premium – California	Premium – Illinois	Mainstream – California	Mainstream – Illinois
Annual Energy Savings[16]	$140	$250	$140	$250
Default Traditional Window Price	$21,000	$21,000	$36,000	$36,000
Range of Premiums to Upgrade	$3,000 - $14,000	$3,000 - $14,000	$3,000 - $14,000	$3,000 - $14,000

7.2.5. Default Traditional Window Price Breakdown (for a typical 300 square feet house)[17]

	Premium	Mainstream
Cost of Traditional Windows	$25,000	$10,000
Cost of Shades	$1,000	$1,000
Cost of Installation	$10,000	$10,000
Total	$36,000	$21,000

[16] *Estimation of annual energy savings using figures from a previous LBNL study. Christian Kohler et al, "Performance Criteria for Residential Zero-Energy Windows" 2005*

[17] *Interviews at HomeDepot, Lowes,… Information include in the Interview Appendix*

7.3. Appendix III

Template for Wholesalers interviews[18]

Date:
Team member:

Location:
Name of the interviewee:

Question	Answer
Who is average customer (homeowner/contractor/installer) and what is their decision process?	
Do you see people coming in looking to retrofit more or are the windows for new houses?	
How many people buy premium windows? How many people buy standard windows?	
What is the average price per window in an order? (premium vs standard)	
What is the average total for an order? What percentage is window cost vs installation cost?	
Do people come in with an idea for a total project price or a price that they want to pay per window?	
Do people implicitly upgrade? (i.e. do people come in looking for a certain type of window and end up upgrading when they see other options and the cost difference?)	
Do buzz-words make customers light up? (i.e. Energy efficiency, sleep management, UV protection)	
What is your most energy efficient window? How popular is it? How do customers respond to it...	
How willing is this store to try new products? How do you select your product portfolio in terms of product features	
How do you handle when an established company rolls out a new product?	

[18] *In bold the most important questions*

How many customers have you served? (ask if talking to a sales person to gauge how informative their information is)	
Do you do business with housing developers?	
What are they charging for the current product that is similar to ours?	
How many people (or what percentage) pick the upgraded window options? (i.e. windows with a special coating or automatic shade)	